Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-85

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DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS OF SHUTTLE MISSION STS-85

7 August 1997

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF PHOTOS

FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

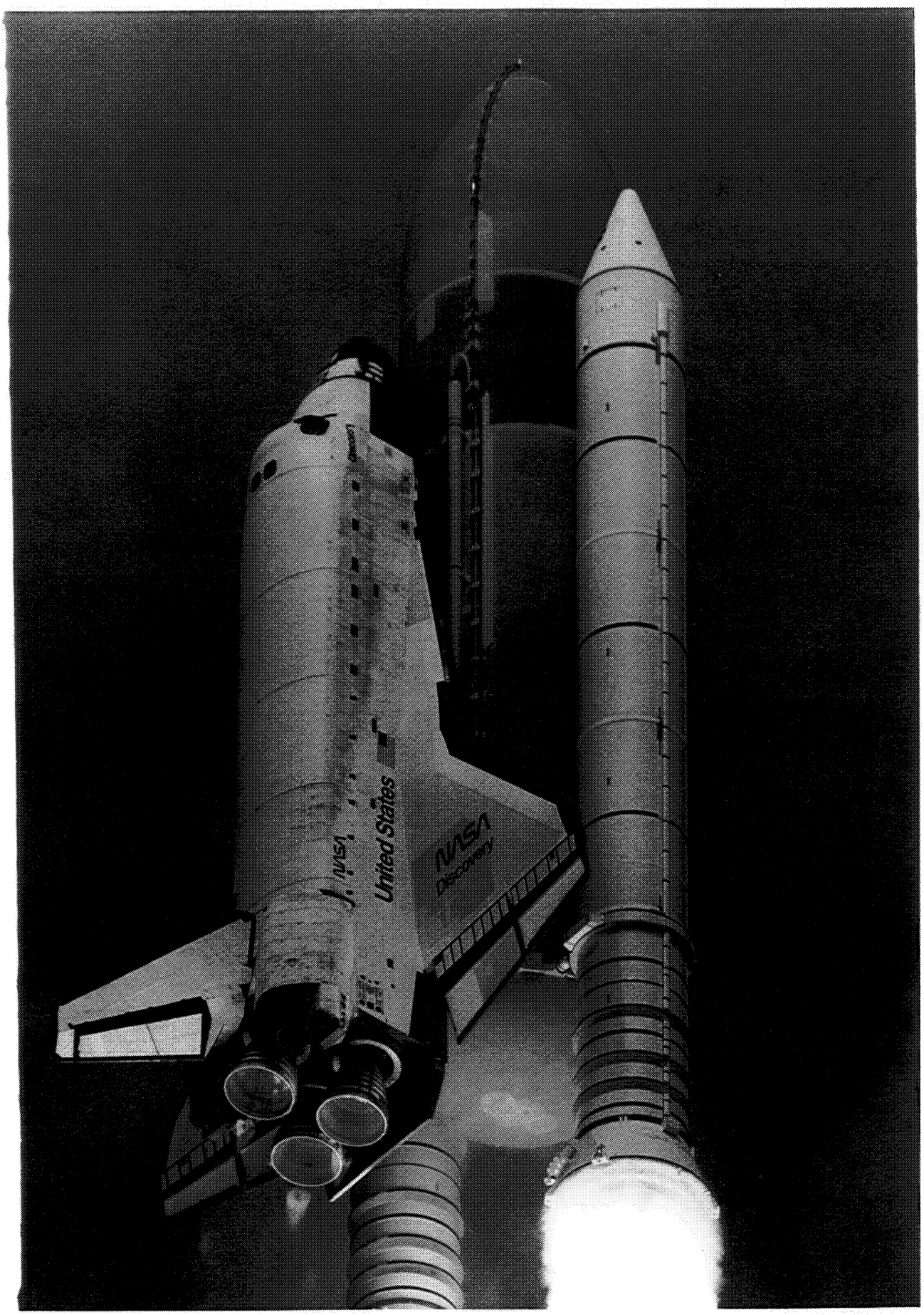


Photo 1: Launch of Shuttle Mission STS-85

1.0 SUMMARY

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 6 August 1997. The detailed walkdown of Pad 39A and MLP-3 also included the primary flight elements OV-103 Discovery (23rd flight), ET-87 (LWT 80), and BI-089 SRB's. There were no significant vehicle or launch pad anomalies. A 6-inch long by 2-inch wide piece of yellow vinyl tape was detected on the right SRB ETA ring near EB-7 and documented on IPR 085V-0091. Since no convenient access to the area was available, the tape would remain in place for flight.

The Final Inspection of the cryoloaded vehicle was performed on 7 August 1997 from 0605 to 0740 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. Due to the warm weather conditions, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

After the 10:41 a.m. (local) launch on 7 August 1997, a debris walk down of Pad 39A was performed. No flight hardware or TPS materials were found. All the T-0 umbilicals operated properly. Overall, damage to the launch pad was minimal. The GH2 vent line was latched in the sixth of eight teeth of the latching mechanism. However, the vent line had skewed to one side during retraction causing one of the vent line support arms to lodge between the two prongs of the latching mechanism. This condition had occurred on previous launches and is not considered an anomaly.

A total of 108 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission. During SSME start-up, the SSME #3 Mach diamond formed, disappeared, then reappeared later after the SSME #2 Mach diamond had formed. A piece of the Macor ceramic thermal isolator fell from the right aft fuselage Flash Evaporator System (FES) port during SSME ignition at 40:56.774 UTC. A 12-14 inch diameter, 12-inch thick piece of instafoam was pulled loose from the right SRB aft skirt as the vehicle began to rise. The foam remained attached to the GN2 purge tube while in the field of view.

Three debris objects with smoke trails were observed moving away from the right SRB exhaust plume at 14:41:02.766 UTC. Good film resolution permitted the identification of the debris objects as chunks of foam originating from the southeast corner of the right SRB exhaust hole. The pieces of foam are believed to be instafoam from the right SRB aft skirt pulled loose at liftoff by the GN2 purge line. The heat of the SRB exhaust plume caused the foam to either burn or outgas resulting in the smoke trails.

No stud hang-ups were observed on any of the eight holddown posts. No ordnance debris or frangible nut pieces fell from the DCS/stud holes.

OV-103 was not equipped to carry ET/ORB umbilical cameras.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums were in excellent condition. No missing TPS or debonds/unbonds were detected over fasteners on the frustums. All eight BSM aero heat shield covers had locked in the fully opened position. The forward skirts exhibited no debonds or missing TPS. Instafoam aft of the left SRB stiffener rings had shrunk causing separation from the trailing edge of the stiffener rings as well as fissures in the foam. Some of the fissure surface area appeared glazed as if exposed to heating. Yellow vinyl tape that had flown attached to the left SRB ETA ring near the lower strut was gone, but a faint outline on the Hypalon paint could still be seen. TPS on the external surface of both aft skirts was intact and in good condition.

Seven of the holddown post Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally. The HDP #5 DCS plunger was obstructed by frangible nut debris. Broaching of the HDP #7 stud bore was caused by a stud hang-up on a previous launch.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-103 Discovery was conducted 19-20 August 1997 at the Kennedy Space Center on SLF runway 33. The Orbiter TPS sustained a total of 102 hits, of which 13 had a major dimension of 1-inch or larger. A comparison of these numbers to statistics from 70 previous missions of similar configuration indicates both the total number of hits, and the number of hits 1-inch or larger, were less than average.

The Orbiter lower surface sustained a total of 37 hits, of which 6 had a major dimension of 1-inch or larger. The largest lower surface tile damage site was located on the body flap centerline. The site measured 2-inches long by 1-inch wide by 0.375-inch maximum depth and was probably caused by an ice impact.

An estimated 25-35 percent of the ceramic insulator surface area on both Flash Evaporator vents (aft fuselage near the body flap hinge) was missing to a maximum depth of 1-inch. Review of launch film item E-17 showed the insulator piece from FES #2 falling aft of the Orbiter during SSME ignition at 14:40:56.615 UTC. However, the missing piece from FES #1 could not be detected in the launch films and most likely was lost sometime later in flight. Both damaged insulators will be replaced, though this process requires the removal of 4 to 5 adjacent tiles at each port.

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be average in size but more than average in quantity. The damage sites are believed to be the result of impacts from excessive RTV adhesive used in attaching paper covers to the FRCS thrusters.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 6 August 1997 at 0900 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC	Chief, ET/SRB Mechanical Systems
G. Katnik	NASA - KSC	Shuttle Ice/Debris Systems
J. Lin	NASA - KSC	Shuttle Ice/Debris Systems
R. Speece	NASA - KSC	Thermal Protection Systems
B. Bowen	NASA - KSC	Infrared Scanning Systems
J. Rivera	NASA - KSC	ET Mechanisms/Structures
B. Davis	NASA - KSC	Digital Imaging Systems
R. Page	NASA - KSC	SSP Integration
M. Valdivia	USA - SPC	Supervisor, ET/SRB Mechanical Systems
J. Blue	USA - SPC	ET Mechanical Systems
R. Seale	USA - SPC	ET Mechanical Systems
W. Richards	USA - SPC	ET Mechanical Systems
M. Wollam	USA - SPC	ET Mechanical Systems
G. Fales	USA - SPC	ET Mechanical Systems
F. Foster	BNA - LSS	Systems Integration
C. Hill	BNA - LSS	Systems Integration
M. Nowling	THIO - LSS	SRM Processing
S. Otto	LMSO - LSS	ET Processing
J. Ramirez	LMSO - LSS	ET Processing
J. Burney	USA - Safety	

3.0 LAUNCH

STS-85 was launched at 97:219:14:41:00.013 UTC (10:41 a.m. local) on 7 August 1997.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 6 August 1997. The detailed walkdown of Pad 39A and MLP-3 also included the primary flight elements OV-103 Discovery (23rd flight), ET-87 (LWT 80), and BI-089 SRB's. There were no significant vehicle or launch pad anomalies. A 6-inch long by 2-inch wide piece of yellow vinyl tape was detected on the right SRB ETA ring near EB-7 and documented on IPR 085V-0091. Since no convenient access to the area was available, the tape would remain in place for flight.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 7 August 1997 from 0605 to 0740 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. Due to the warm weather conditions, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, particularly those areas not visible from remote fixed scanners, and to scan for unusual temperature gradients.

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster covers were intact and dry. Ice/frost and condensate had formed on SSME #1 and #2 heat shield-to-nozzle interfaces. The SSME #3 heat shield was dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers were close to ambient temperatures. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature supplied by THIO was 81 degrees F, which was within the required range of 44-86 degrees F.

3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a comparison to infrared scanner point measurements. The program predicted condensate, but no ice or frost, on the ET acreage TPS.

The Final Inspection Team observed moderate condensate, but no ice or frost accumulations, on the LO2 tank acreage. TPS surface temperatures averaged 67 degrees F. A small repair on the +Z barrel section was intact with no visible frost lines.

The intertank acreage exhibited no TPS anomalies. Ice/frost accumulation on the GUCP appeared typical. However, venting from the purge shroud resulted in more visible vapor than usual.

The Final Inspection Team observed moderate condensate, but no ice or frost accumulations, on the LH2 tank acreage. TPS surface temperatures averaged 62-66 degrees F. All TPS repairs on the +Z side of the LH2 tank were intact with no visible frost lines.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

No visible stress relief crack had formed on the -Y vertical strut forward facing TPS.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost accumulations were limited to small patches on the aft and inboard sides. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Typical amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier outboard side and forward surface. Smaller than usual ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch. All TPS repairs on the umbilical were nominal.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch.

No leaks were observed on the GUCP or the LO2 and LH2 Orbiter T-0 umbilicals.

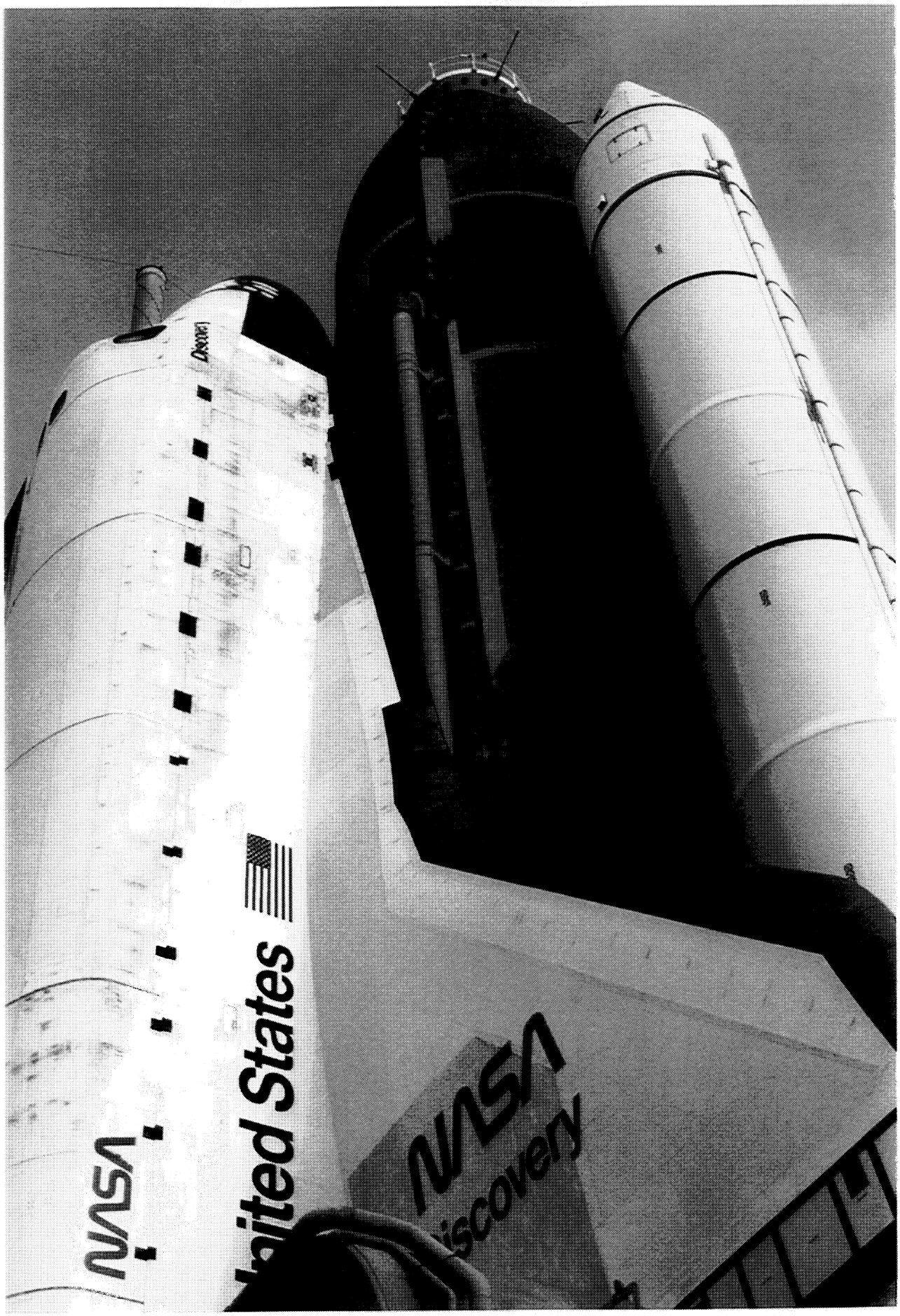


Photo 2: STS-85 Ready for Launch

OV-103 Discovery (23rd flight), ET-87 (LWT 80), and BI-089 SRB's

Photo 3: LO2 Tank and Intertank After Cryoload

The Final Inspection Team observed light condensate, but no ice or frost accumulations, on the LO2 tank. TPS surface temperatures averaged 67 degrees F.

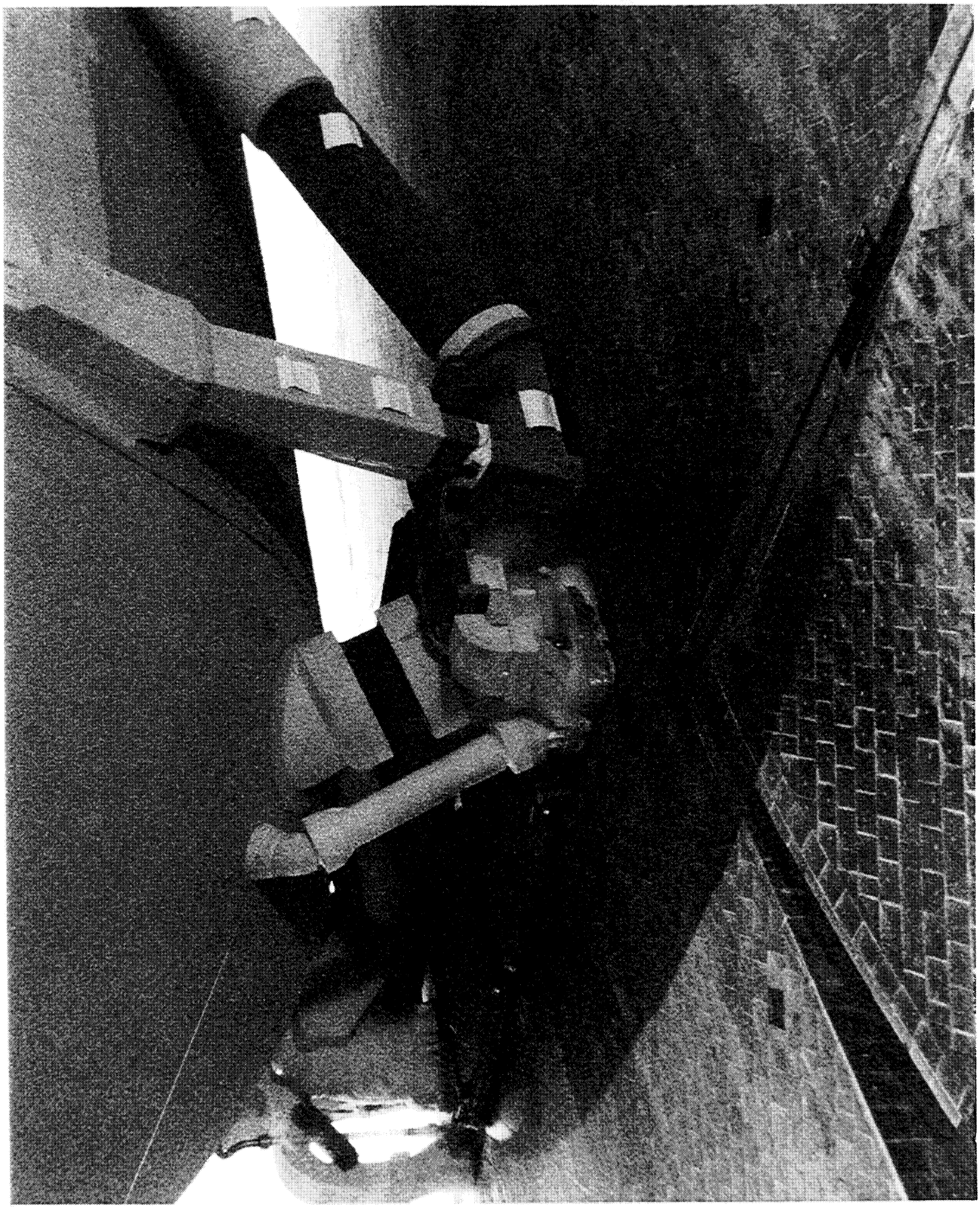


Photo 4: ET/Orbiter LH2 Umbilical

Typical amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier outboard side and forward surface. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents.

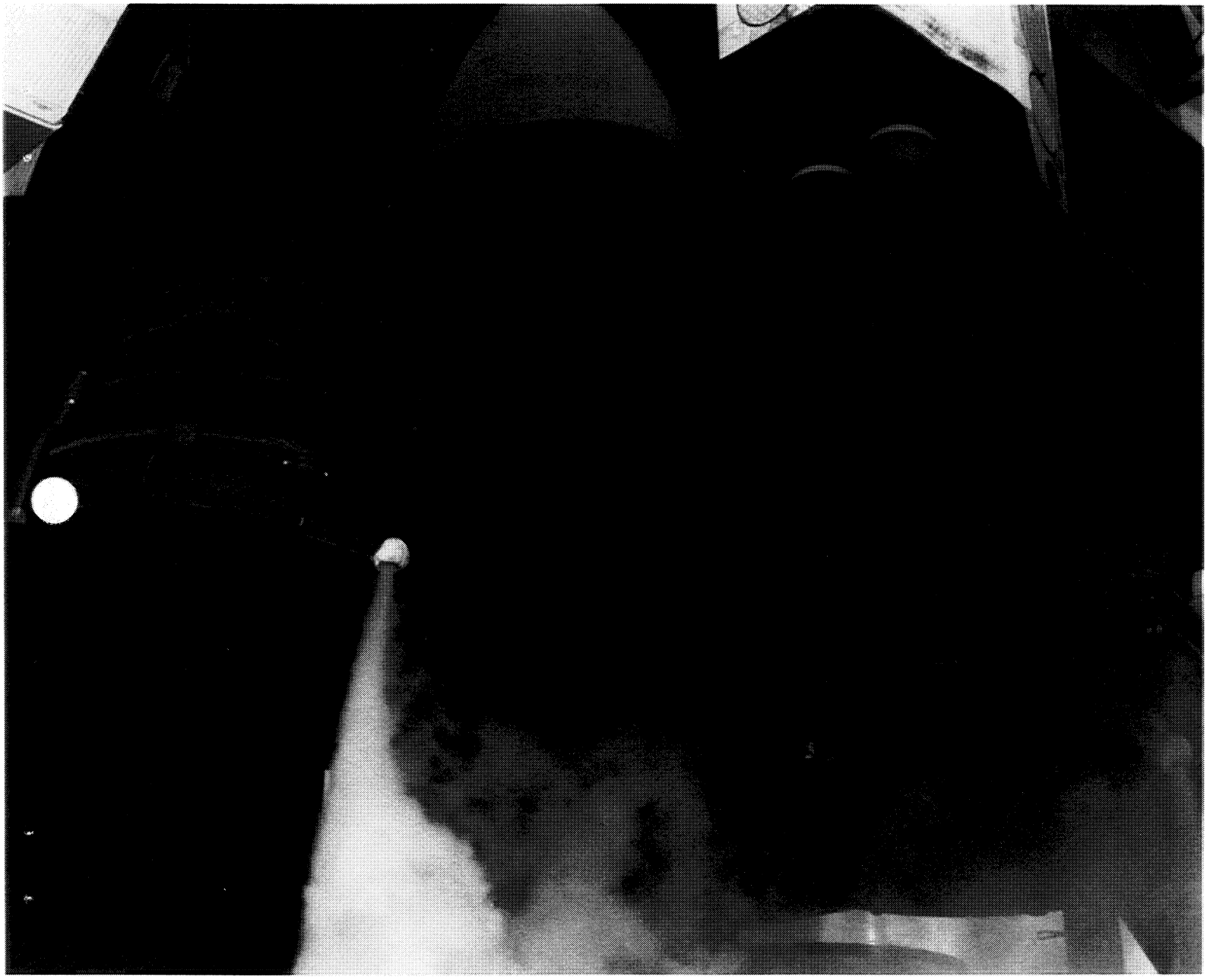


Photo 5: Overall View of SSME's

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of MLP 3, Pad A FSS and RSS was conducted on 7 August 1997 from Launch + 2 to 3.5 hours.

SRB hold down post erosion generally was typical. Boeing - Downey reported an Orbiter liftoff lateral acceleration of 0.14 g's, which is considered the threshold for stud hang-ups. Preliminary observations of the south holddown posts from the MLP deck revealed no obvious signs of a stud hang-up. Hold down post launch films were reviewed Monday and revealed no stud hang-ups. Aft skirt purge lines and T-0 umbilicals exhibited typical exhaust plume damage.

The Tail Service Masts (TSM) and Orbiter Access Arm (OAA) had no visible damage. The TSM bonnets were closed.

The GH2 vent line was latched in the sixth of eight teeth of the latching mechanism. However, the vent line had skewed to one side during retraction causing one of the vent line support arms to lodge between the two prongs of the latching mechanism. This condition had occurred on previous launches and is not considered an anomaly. The GUCP 7-inch QD surface and a leg thrust bar had been damaged by contact with the steel cable retract lanyard.

The flexible part of the southwest GOX vent duct was torn from the hood flange. This damage was caused by SRB plume impingement after the vehicle cleared the tower.

Other pad damage included:

A large electrical outlet at the MLP northwest corner was missing a retainer cap.

Two utility boxes on the west side of the FSS 95 foot level were missing 4-foot by 4-foot covers, both of which were found west of the pad near the trailer complexes.

A metal putty knife was found on the FSS 215 foot level.

Approximately 160 feet of security fence on the north side of the pad was down or leaning.

A 3-foot by 4-foot area of concrete embankment on the north side of the pad was broken.

These inspections noted minimal overall damage to the pad.

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 83 films and videos, which included twenty-seven 16mm films, seventeen 35mm films, and thirty-nine videos, were reviewed starting on launch day.

During SSME start-up, the SSME #3 Mach diamond formed, disappeared, then reappeared later after the SSME #2 Mach diamond had formed (E-19, -76, -77; OTV 070, 051) according to the following times:

14:40:56.758 UTC	Mach diamond formed
14:40:56.827 UTC	Mach diamond disappeared
14:40:56.946 UTC	Mach diamond reappeared

As reported by MSFC, the apparent dissipation of the Mach diamond correlates with an oscillation in main chamber pressure that is associated with a characteristic hydrodynamic stall and recovery of the high pressure oxidizer pump. The unusual disappearance and reappearance of the Mach diamond is a combination of factors including the pump stall phenomenon, main chamber pressure level, nozzle physical uniqueness, and external environmental conditions.

SSME ignition caused pieces of ice to fall from the ET/ORB umbilicals. Several pieces of ice contacted the umbilical cavity sills and were deflected outward. No tile damage was visible (OTV-009).

Tile surface coating material was lost during ignition from two places on the base heatshield outboard of SSME #3, one place on the base heat shield outboard of SSME #2, and three places on the aft surface of the LH RCS stinger (E-17, -18; OTV 054).

OTV 060 showed a frost line around the louver, but no missing topcoat from the foot print area, after the GOX vent hood was retracted. OTV 061 showed frost spots over the bolt heads on both sides of the louver and frost in a SLA serration at the lower right corner of the louver. Two light spots in the grid may be small areas of missing topcoat. A white object aft of the grid appeared to be a winged insect. Another white object, which fell aft and was visible against Orbiter black tiles, is believed to be a moth rather than an ice particle.

A flat, thin piece of debris, which appeared to be close to the E-18 camera lens, crossed the field of view during SSME ignition at 40:55.662 UTC. Three more thin, irregular shaped objects, which most likely were pieces of deck scale, first appeared at 40:55.555 UTC on film item E-17 and also appeared to be close to the camera lens. No contact with flight hardware was observed. In general, the films revealed more than usual amounts of deck debris being drawn into the SSME and SRB exhaust holes.

A piece of the Macor ceramic thermal isolator fell from the right aft fuselage Flash Evaporator System (FES) port during SSME ignition at 40:56.774 UTC (E-5, 17).

A dark object visible against the Orbiter right fuselage falling aft at 14:41:01.279 UTC was observed in film item E-52, but not E-54. The object is most likely an insect on or near the E-52 camera lens.

A large, 12-14 inch diameter, 12-inch thick piece of instafoam was pulled loose from the right SRB aft skirt as the vehicle began to rise. The foam remained attached to the GN2 purge tube while in the field of view (E-8).

Three debris objects with smoke trails were observed moving away from the right SRB exhaust plume at 14:41:02.766 UTC. (E-20, -63, -77; OTV 033). Good film resolution permitted the identification of the debris objects as chunks of foam originating from the southeast corner of the right SRB exhaust hole. The six pieces of foam debris, three of which exhibited smoke trails, are believed to be instafoam from the right SRB aft skirt pulled loose at liftoff by the GN2 purge line. The heat of the SRB exhaust plume caused the foam to either burn or outgas resulting in the smoke trails.

No stud hang-ups were observed on any of the eight holddown posts. No ordnance debris or frangible nut pieces fell from the DCS/stud holes.

Numerous pieces of SRB throat plug were ejected from the right SRB exhaust hole near holddown posts #1 and #2, but none of the pieces contacted the vehicle (E-5; OTV 063). A large, light colored debris object, believed to be SRB throat plug material, appeared to originate from the SRB exhaust hole and moved northward away from the vehicle at 14:41:02.901 UTC (E-52).

SRB separation appeared normal. Some pieces of slag were visible falling from the SRB plume during and after separation (TV-13).

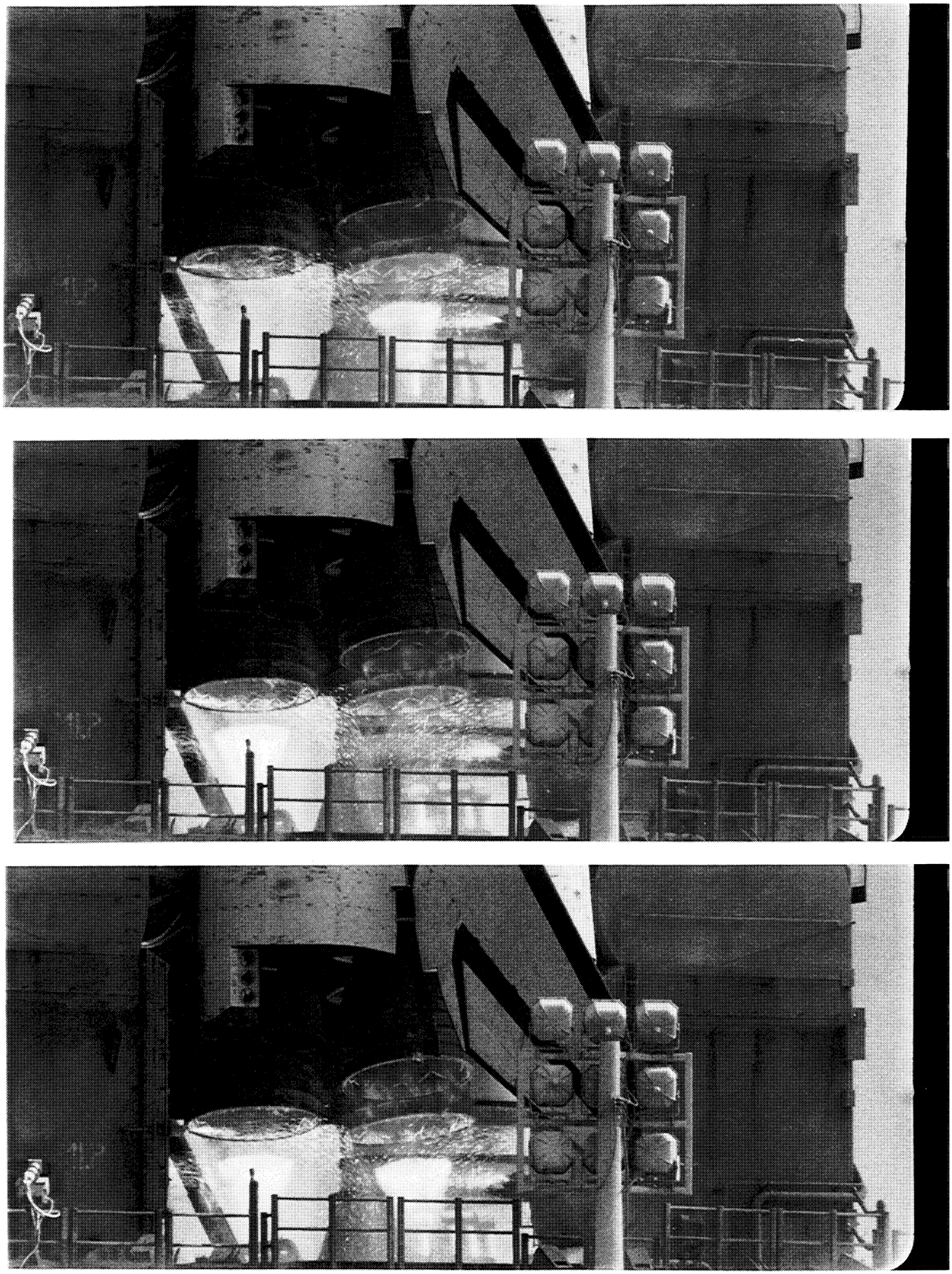


Photo 6: SSME Mach Diamond Formation

During SSME start-up, the SSME #3 Mach diamond formed, disappeared then reappeared later after the SSME #2 Mach diamond had formed

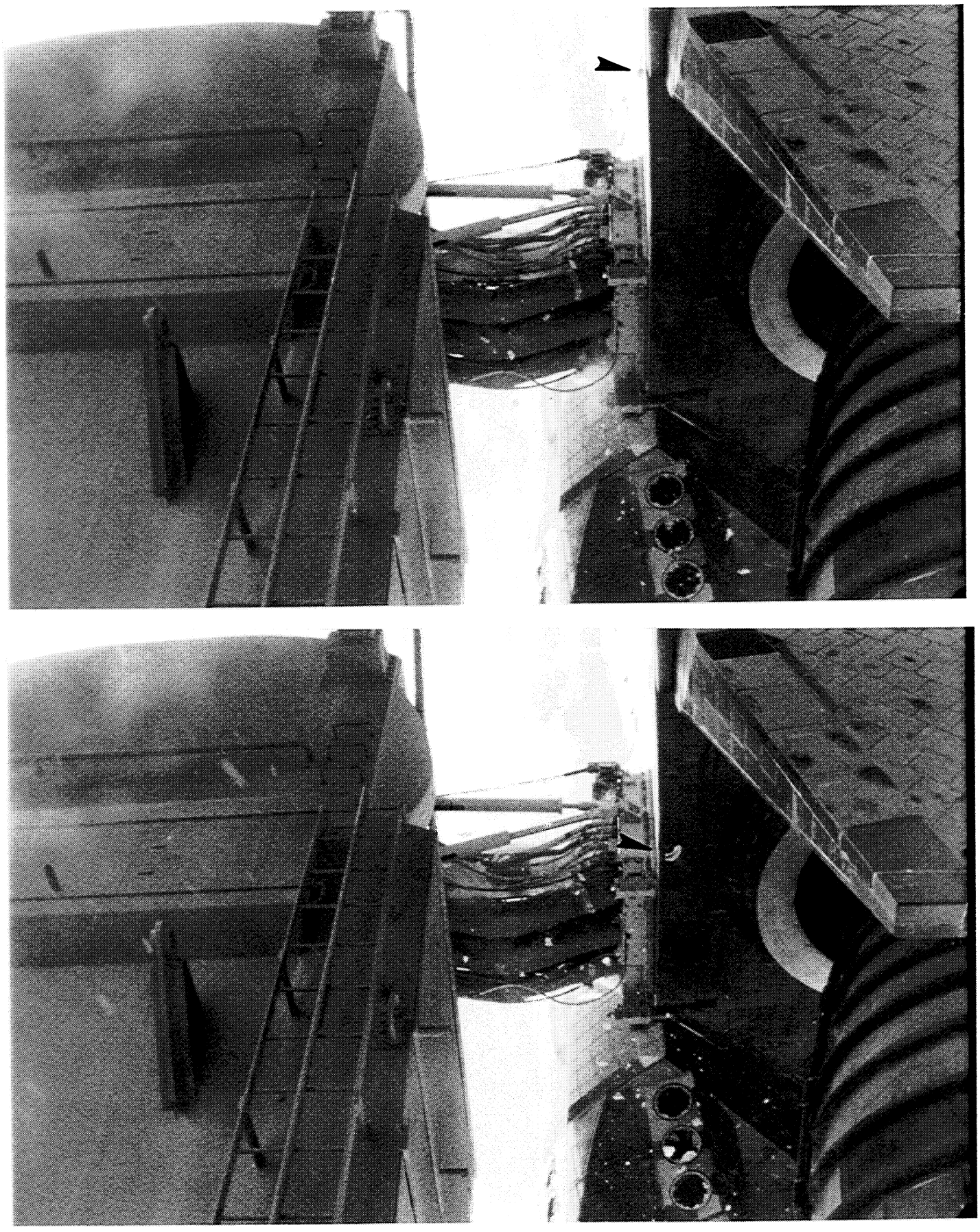


Photo 7: FES Thermal Isolator

A piece of the Macor ceramic thermal isolator fell from the right aft fuselage Flash Evaporator System (FES) port during SSME ignition at 40:56.774 UTC

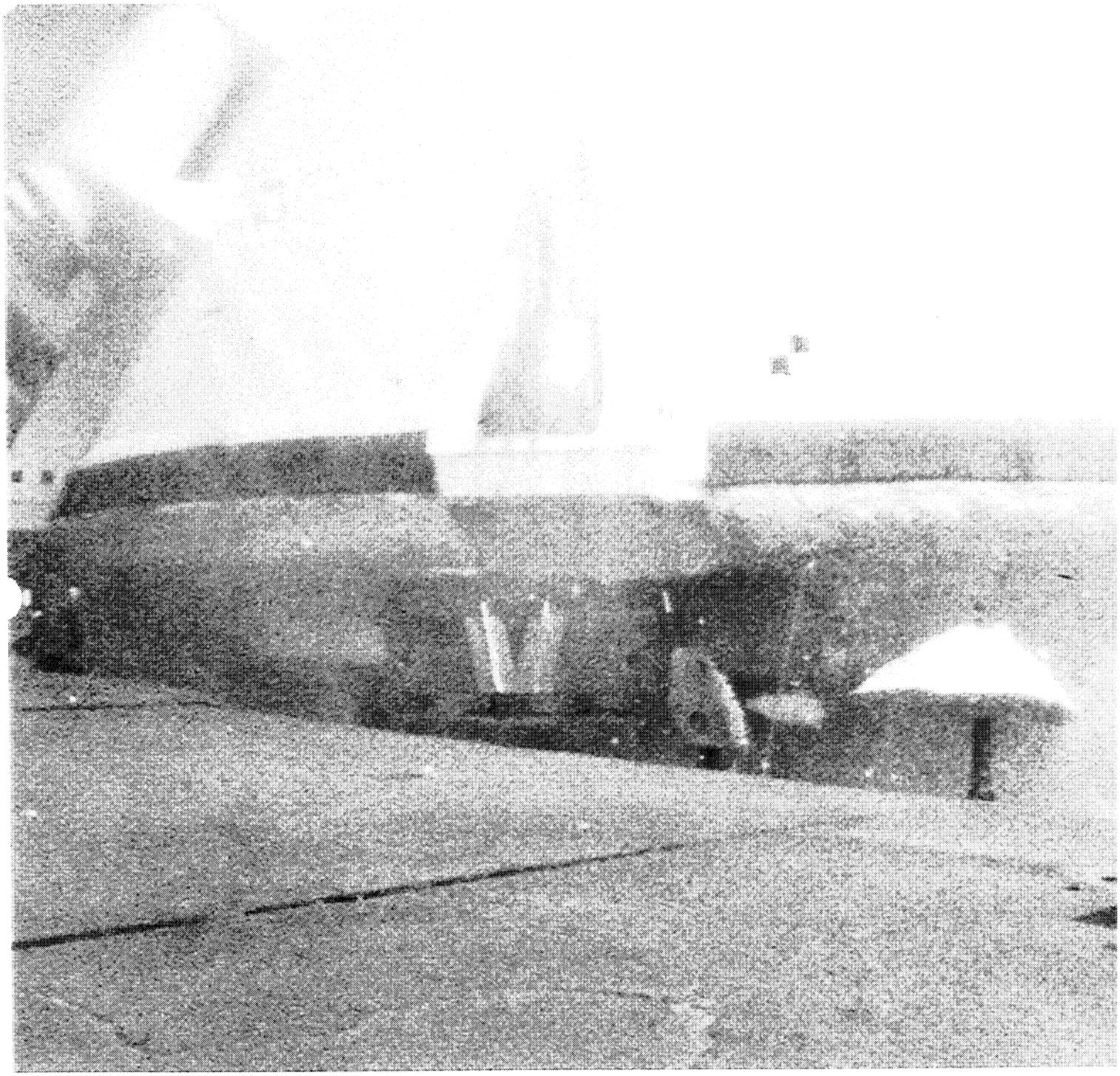


Photo 8: Foam on GN2 Purge Line

A 12-14 inch diameter, 12-inch thick piece of instafoam was pulled loose from the right SRB aft skirt as the vehicle began to rise. The foam remained attached to the GN2 purge tube while in the field of view.

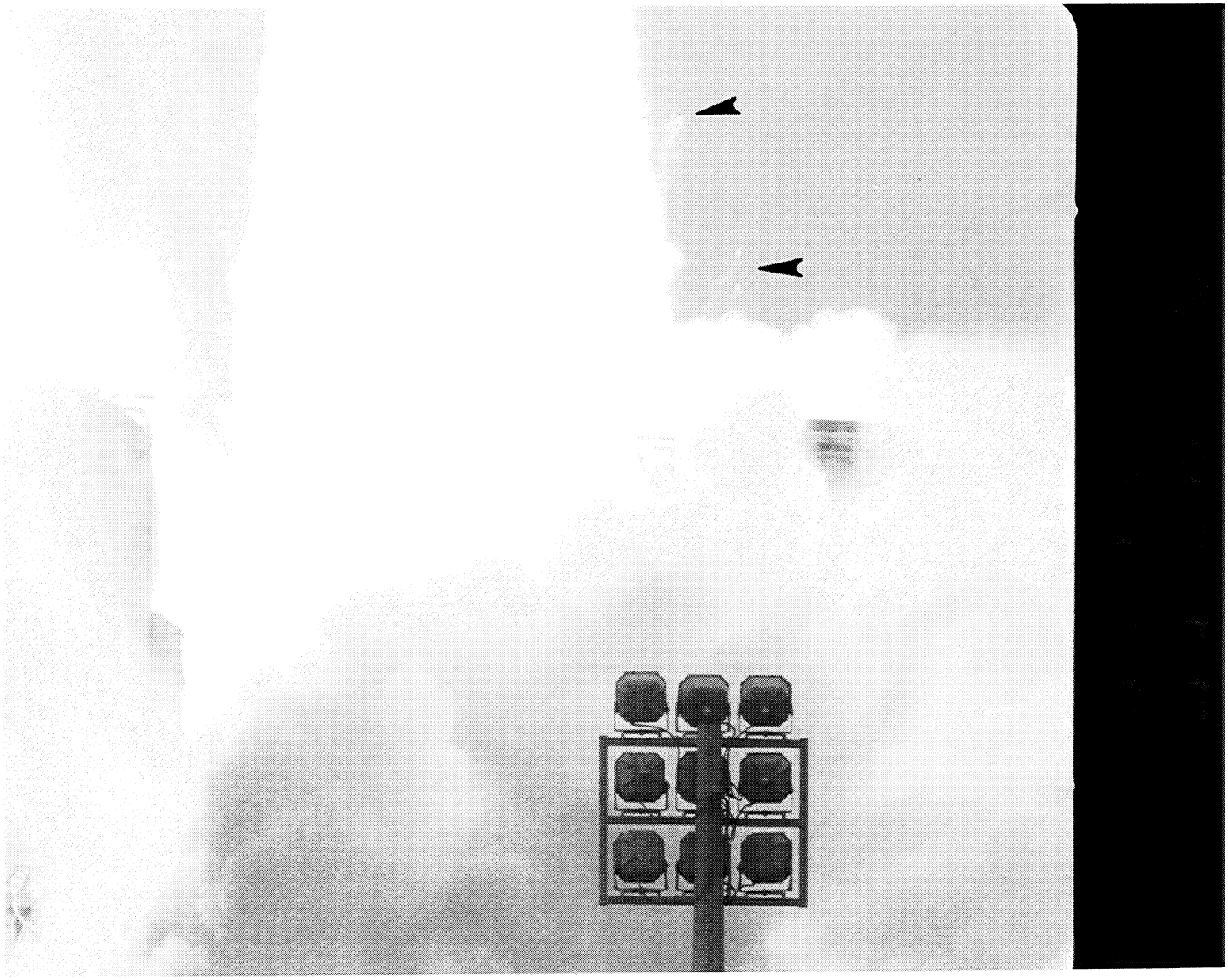


Photo 9: Foam with Smoke Trails

Three debris objects with smoke trails moved away from the right SRB exhaust plume at 14:41:02.766 UTC. Good film resolution permitted the identification of the debris objects as chunks of foam originating from the southeast corner of the right SRB exhaust hole. The pieces of foam are believed to be instafoam from the right SRB aft skirt pulled loose at liftoff by the GN2 purge line. The heat of the SRB exhaust plume caused the foam to either burn or outgas resulting in the smoke trails.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-103 was not equipped to carry umbilical cameras. Hand-held photography by the flight crew, which consisted of 37 still 35mm images and one seven minute video, showed no anomalies.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 24 films and videos, which included ten 35mm large format films, two 16mm films, and twelve videos, were reviewed.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. The main landing gear contacted the runway almost simultaneously slightly west of centerline. The Orbiter rolled east of the centerline before being steered back onto the centerline. Drag chute deployment appeared nominal. Touchdown of the nose landing gear was smooth. Rollout and wheel stop were uneventful. No significant TPS damage was visible in the films.

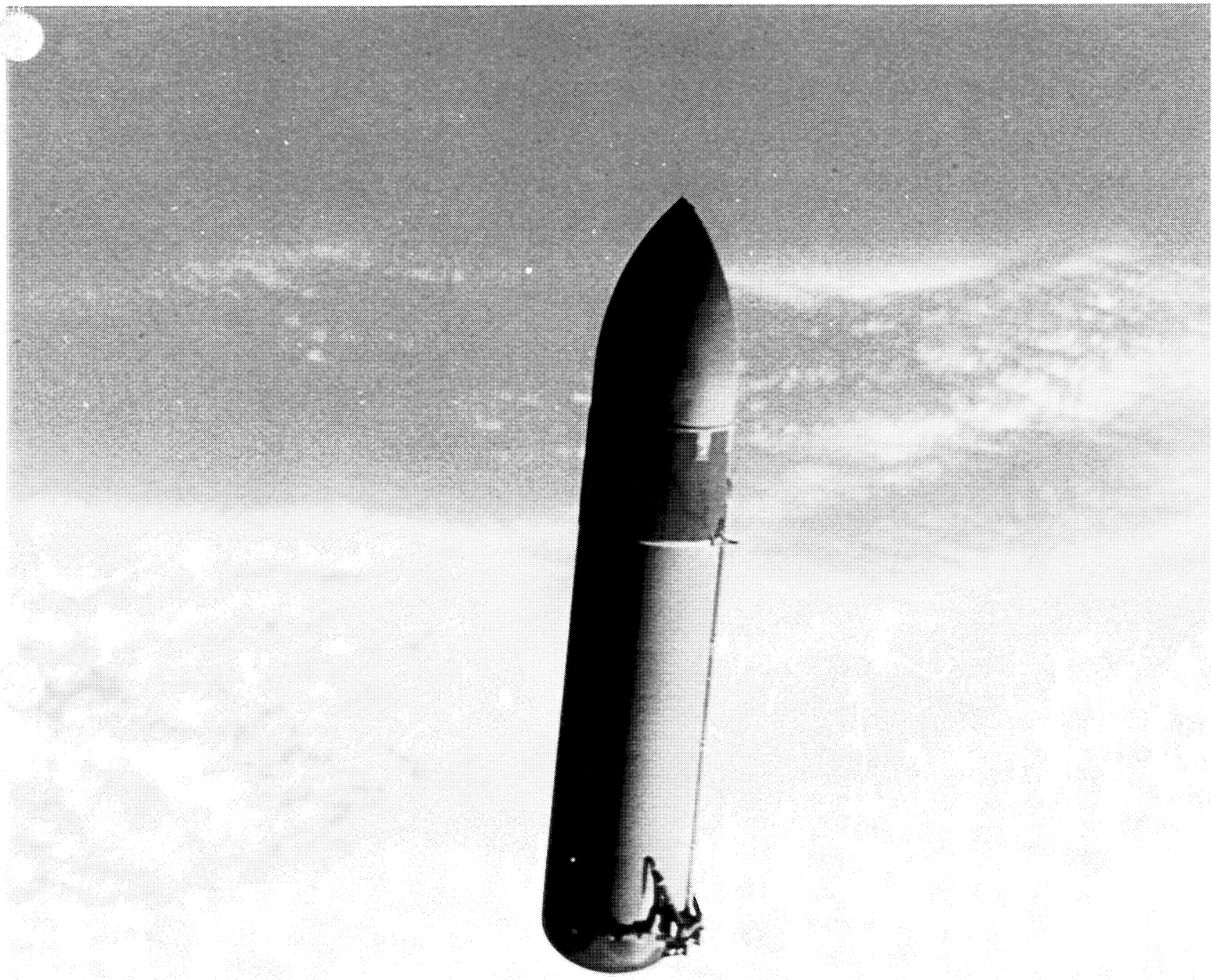


Photo 10: ET Separation from Orbiter

Flight crew hand-held view of the External Tank after separation from the Orbiter showed no anomalies

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-089 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAS Hangar AF on 11 August 1997.

Both frustums were in excellent condition. No TPS was missing and no debonds/unbonds were detected over fasteners. Virtually none of the Hypalon paint had blistered. All eight BSM aero heat shield covers had locked in the fully opened position.

The forward skirts exhibited no debonds or missing TPS. RSS antennae covers/phenolic base plates were intact. The +Z antenna base plate on the left SRB exhibited two delaminated phenolic layers. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. All frustum severance ring pins and retainer clips were intact.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension. Cork was damaged on the left SRB center field joint leading edge at the 40 degree location. Examination of the damage site revealed no sooting. The damage is believed to have been caused by handling rather than an in-flight debris impact. The dive crew reported contact with that area of the booster while submerging the diver operated plug (DOP).

Separation of the aft ET/SRB struts appeared normal. Several stiffener rings and the left SRB IEA were damaged by water impact. Instafoam aft of the left SRB stiffener rings had shrunk causing separation from the trailing edge of the stiffener rings as well as fissures in the foam. Some of the fissure surface area appeared glazed as if exposed to heating.

Yellow vinyl tape that had flown attached to the left SRB ETA ring near the lower strut was gone, but a faint outline on the Hypalon paint could still be seen.

TPS on the external surface of both aft skirts was intact and in good condition.

Seven of the holddown post Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally. The HDP #5 DCS plunger was obstructed by frangible nut debris. Broaching of the HDP #7 stud bore was caused by a stud hang-up on a previous launch. High speed films of the holddown posts confirmed no stud hang-up on the STS-85 launch.

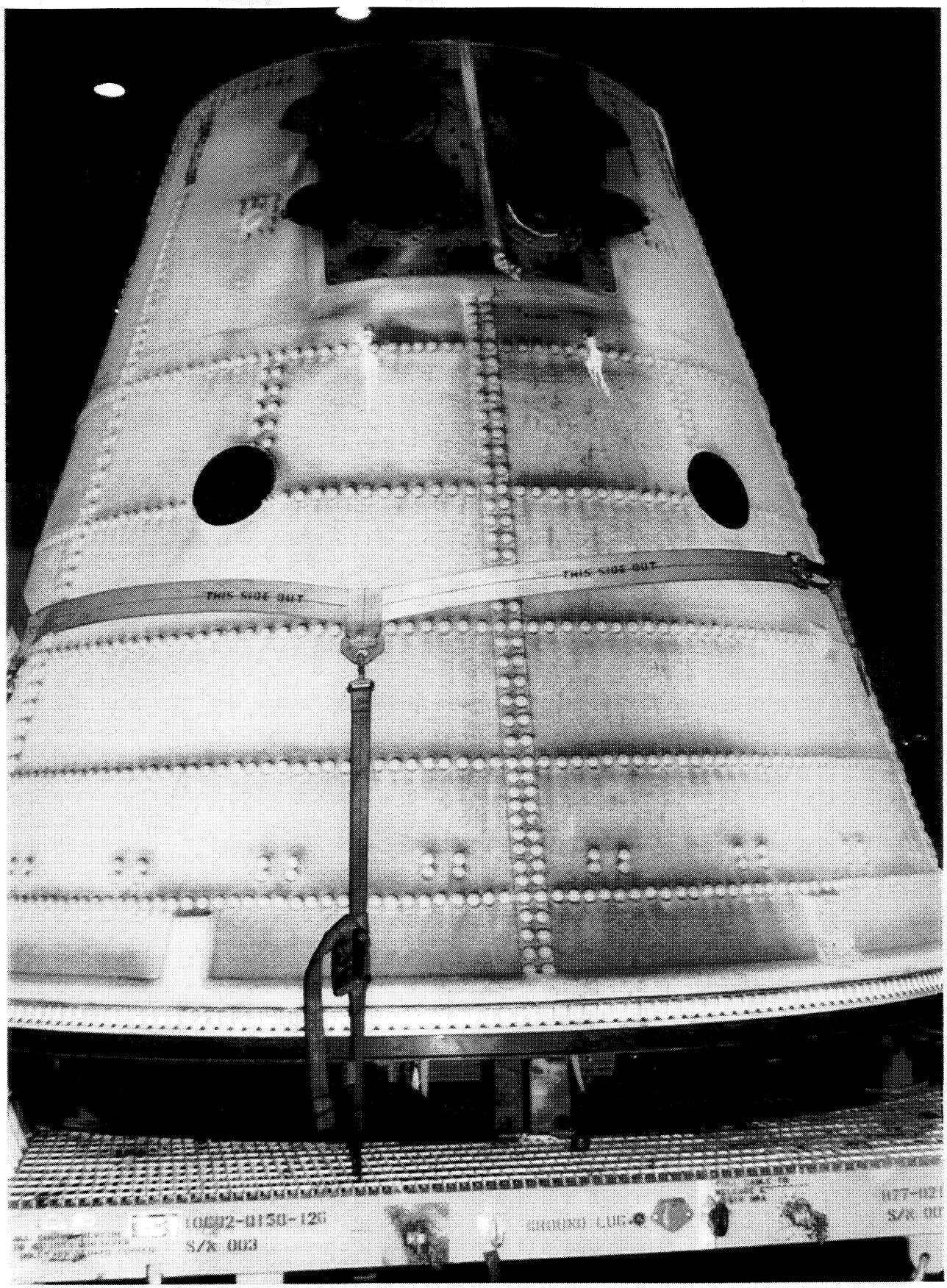


Photo 11: Frustum Post Flight Condition

Both frustums were in excellent condition. No TPS was missing and no debonds/unbonds were detected over fasteners. Virtually none of the Hypalon paint had blistered. All eight BSM aero heat shield covers had locked in the fully opened position.

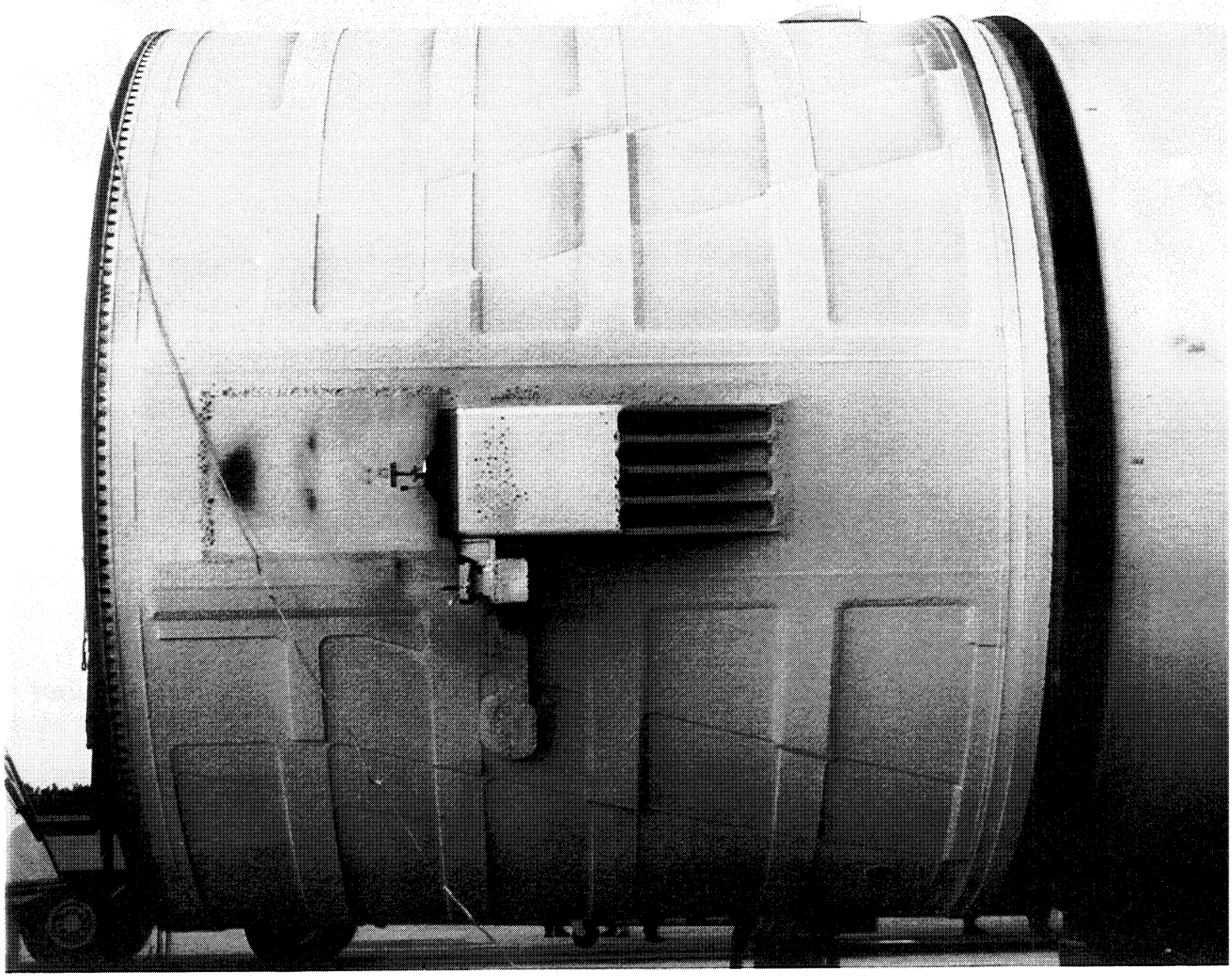


Photo 12: Forward Skirt Post Flight Condition

The forward skirts exhibited no debonds or missing TPS. RSS antennae covers/phenolic base plates were intact. The +Z antenna base plate on the left SRB exhibited two delaminated phenolic layers. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. All frustum severance ring pins and retainer clips were intact.

Photo 13: Aft Booster/Aft Skirt Post Flight Condition

Separation of the aft ET/SRB struts appeared normal.
Several stiffener rings and the left SRB IEA were damaged by water impact.

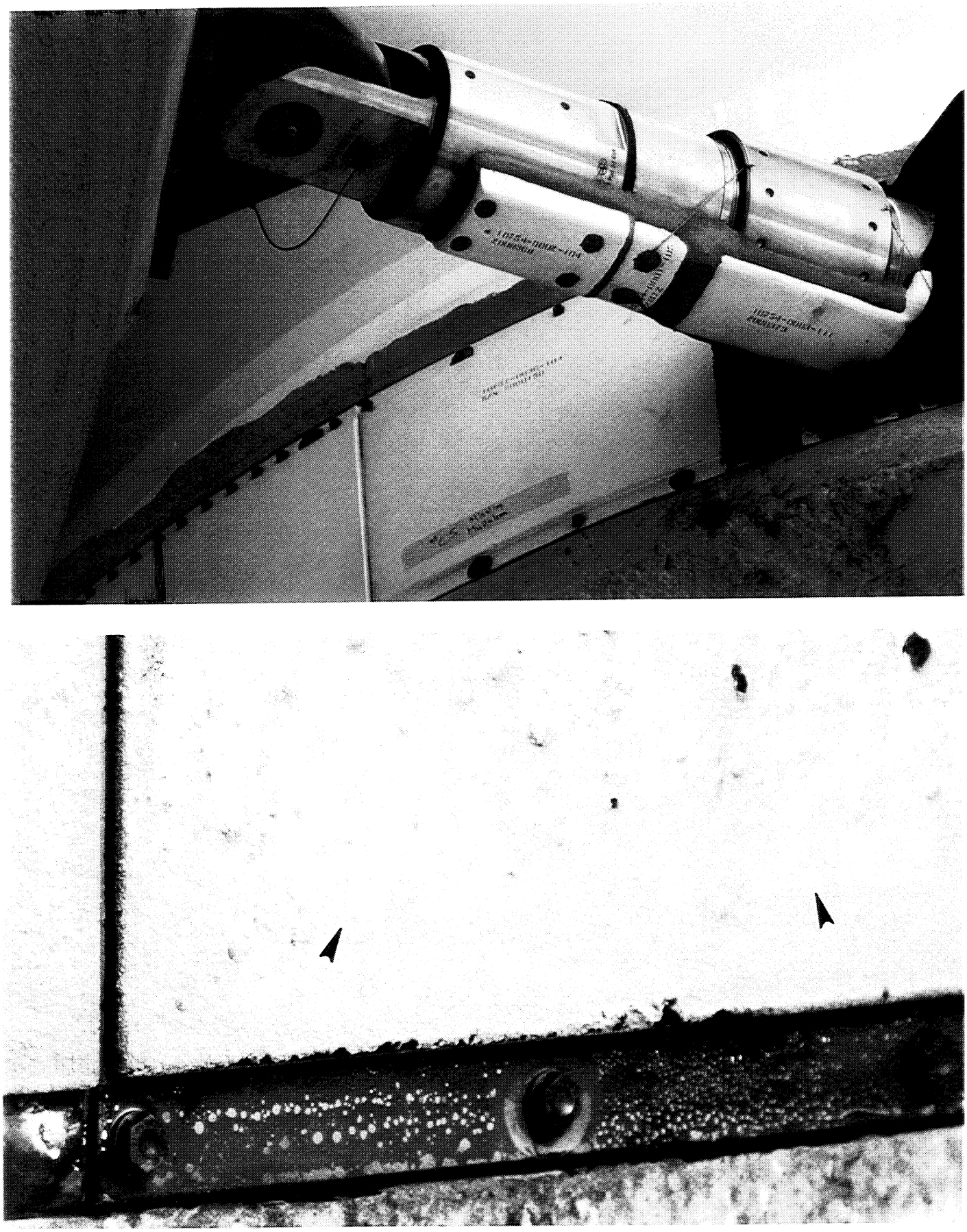


Photo 14: Vinyl Tape on ETA Ring

Yellow vinyl tape that had flown attached to the left SRB ETA ring near the lower strut was gone, but a faint outline on the Hypalon paint could still be seen

Photo 15: Stiffener Ring Foam Shrinkage

Instafoam aft of the left SRB stiffener rings had shrunk causing separation from the trailing edge of the stiffener rings as well as fissures in the foam. Some of the fissure surface area appeared glazed as if exposed to heating.

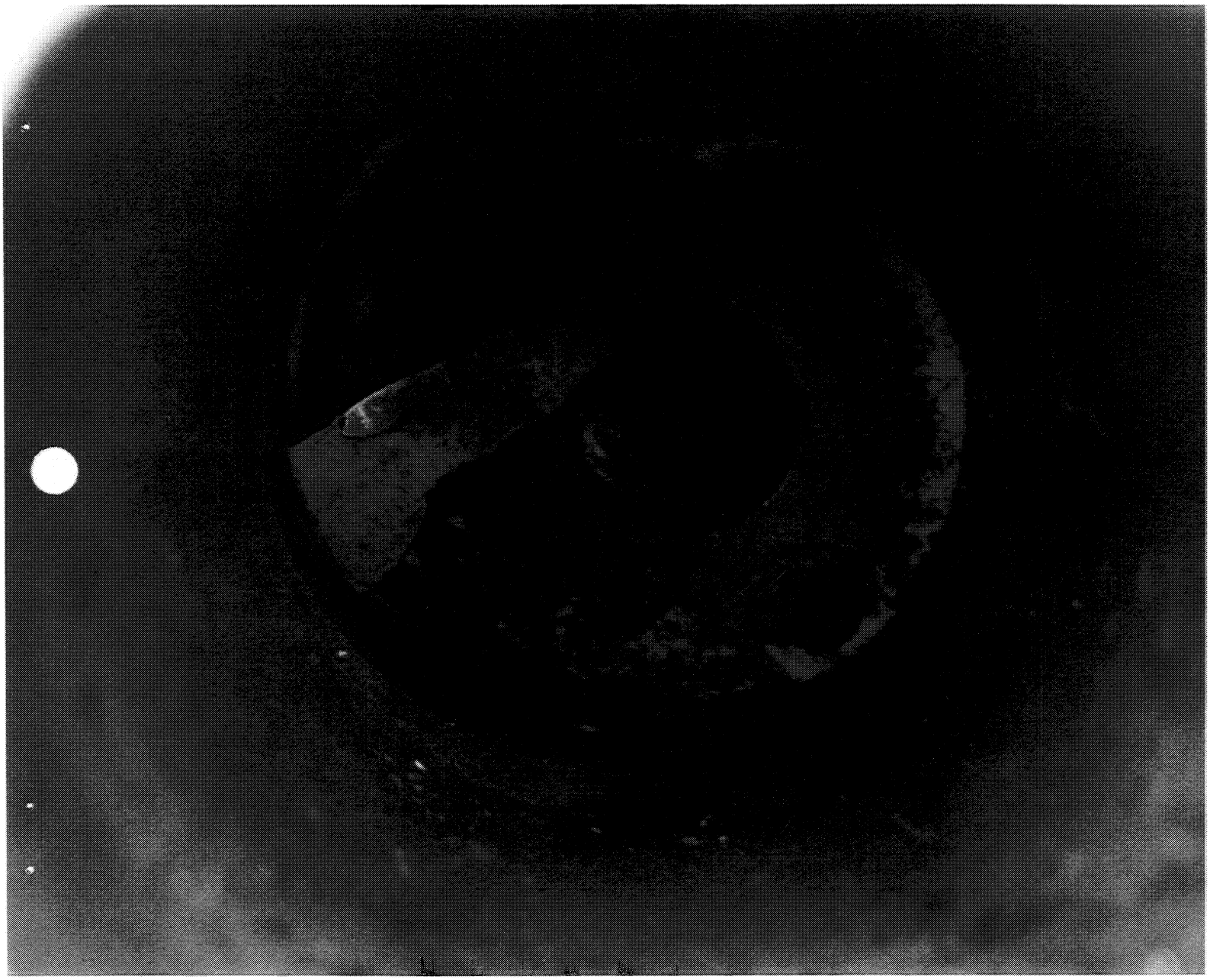


Photo 16: HDP #5 DCS Plunger Obstruction

Seven of the holddown post Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally. The HDP #5 DCS plunger was obstructed by frangible nut debris.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing inspection of OV-103 Discovery was conducted 19-20 August 1997 at the Kennedy Space Center on SLF runway 33 and in the Orbiter Processing Facility bay #3. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 102 hits, of which 13 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 70 previous missions of similar configuration (excluding missions STS-23, 24, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits, and the number of hits 1-inch or larger, were less than average (Reference Figures 1-4).

The following table breaks down the STS-85 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	6	37
Upper surface	7	41
Right side	0	9
Left side	0	5
Right OMS Pod	0	4
Left OMS Pod	0	6
TOTALS	13	102

The Orbiter lower surface sustained a total of 37 hits, of which 6 had a major dimension of 1-inch or larger. The largest lower surface tile damage site was located on the body flap centerline. The site measured 2-inches long by 1-inch wide by 0.375-inch maximum depth and was probably caused by an ice impact.

Tile damage sites around the LH2 and LO2 ET/ORB umbilicals were typical. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream.

No tile damage from micrometeorites or on-orbit debris was identified during this inspection.

The tires were reported to be in good condition for a landing on the KSC concrete runway with most of the wear and tear occurring on both main landing gear inboard tires.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities. Although the EO-3 retainer springs appeared to be in nominal configuration, the EO-2 retainer springs were dislodged. This condition has been observed on previous flights. Five clips were missing from the EO-3 fitting "salad bowl". Virtually no umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect.

A thin, metal spacer between two bolt heads on the inside surface of the LO2 ET door near the forward outboard corner was bent/peeled. This same condition has occurred on previous flights on different Orbiters.

The SSME Dome Mounted Heat Shield (DMHS) closeout blankets were generally in good condition. However, a blanket panel on SSME #1 at the 5-6 o'clock position and another panel on SSME #2 at the 3 o'clock position were torn/frayed.

A 4-inch by 2-inch corner was missing from a base heat shield tile located in the area between SSME #2/3 and the body flap hinge. Tiles on the vertical stabilizer "stinger" were intact and undamaged.

An estimated 25-35 percent of the ceramic insulator surface area on both Flash Evaporator System (FES) vents (aft fuselage near the body flap hinge) was missing to an approximate maximum depth of 1-inch. Review of launch film item E-17 showed the insulator piece from FES #2 falling aft of the Orbiter during SSME ignition at 14:40:56.615 UTC. However, the missing piece from FES #1 could not be detected in the launch films and most likely was lost sometime later in flight. Both damaged thermal insulators will be replaced, though this process requires the removal of 4 to 5 adjacent black tiles at each vent.

No ice adhered to the payload bay door. No significant tile damage occurred on the leading edges of the OMS pods or vertical stabilizer.

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be average in size but more than average in quantity. The damage sites are believed to be the result of impacts from excessive RTV adhesive used in attaching paper covers to the FRCS thrusters.

The post landing walkdown of Runway 33 was performed immediately after landing. No debris concerns were identified. All drag chute hardware was recovered and appeared to have functioned normally.

In summary, both the total number of Orbiter TPS debris hits, and the number of hits 1-inch or larger, were less than average when compared to previous missions (Reference Figure 5).

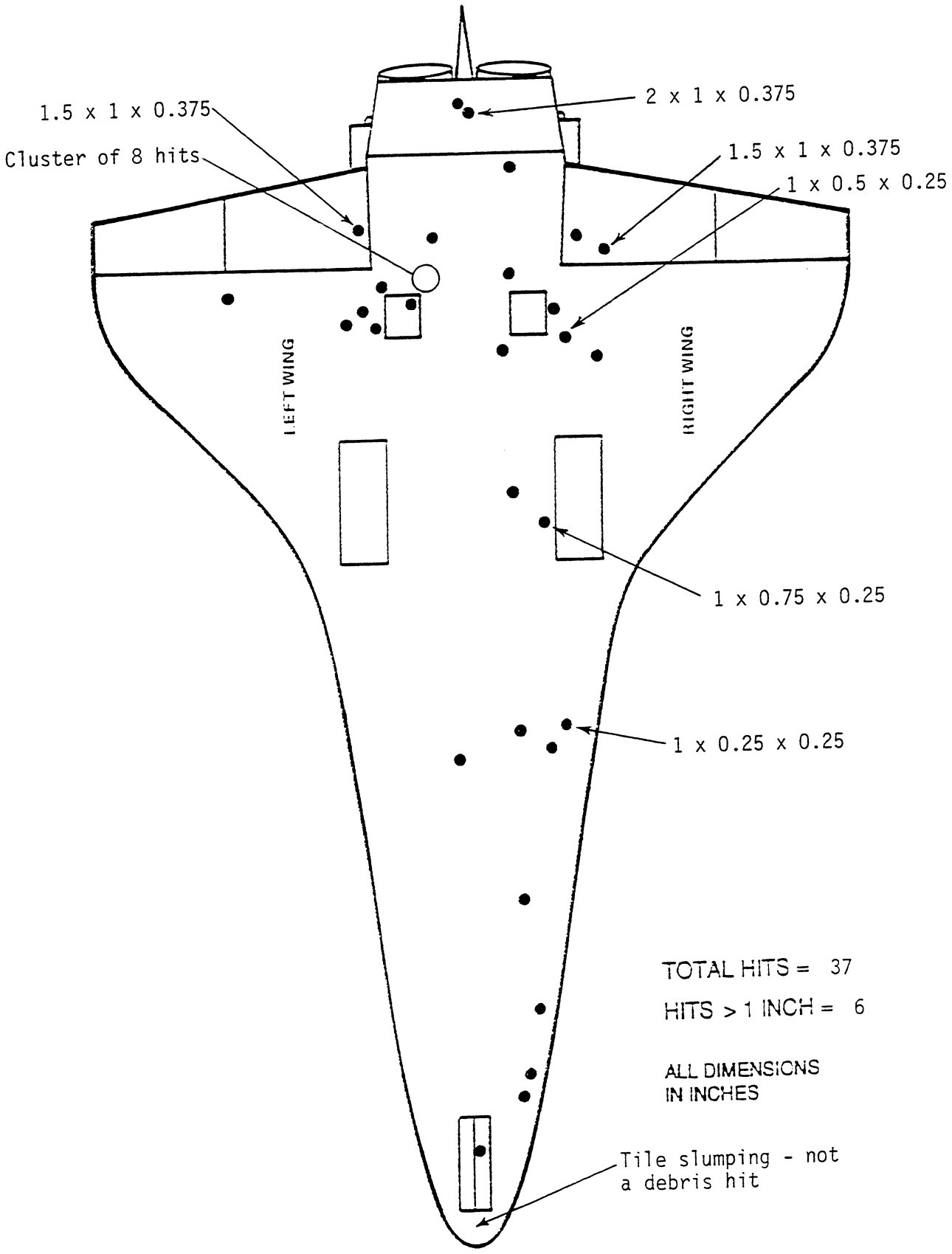


Figure 1: Orbiter Lower Surface Debris Damage Map

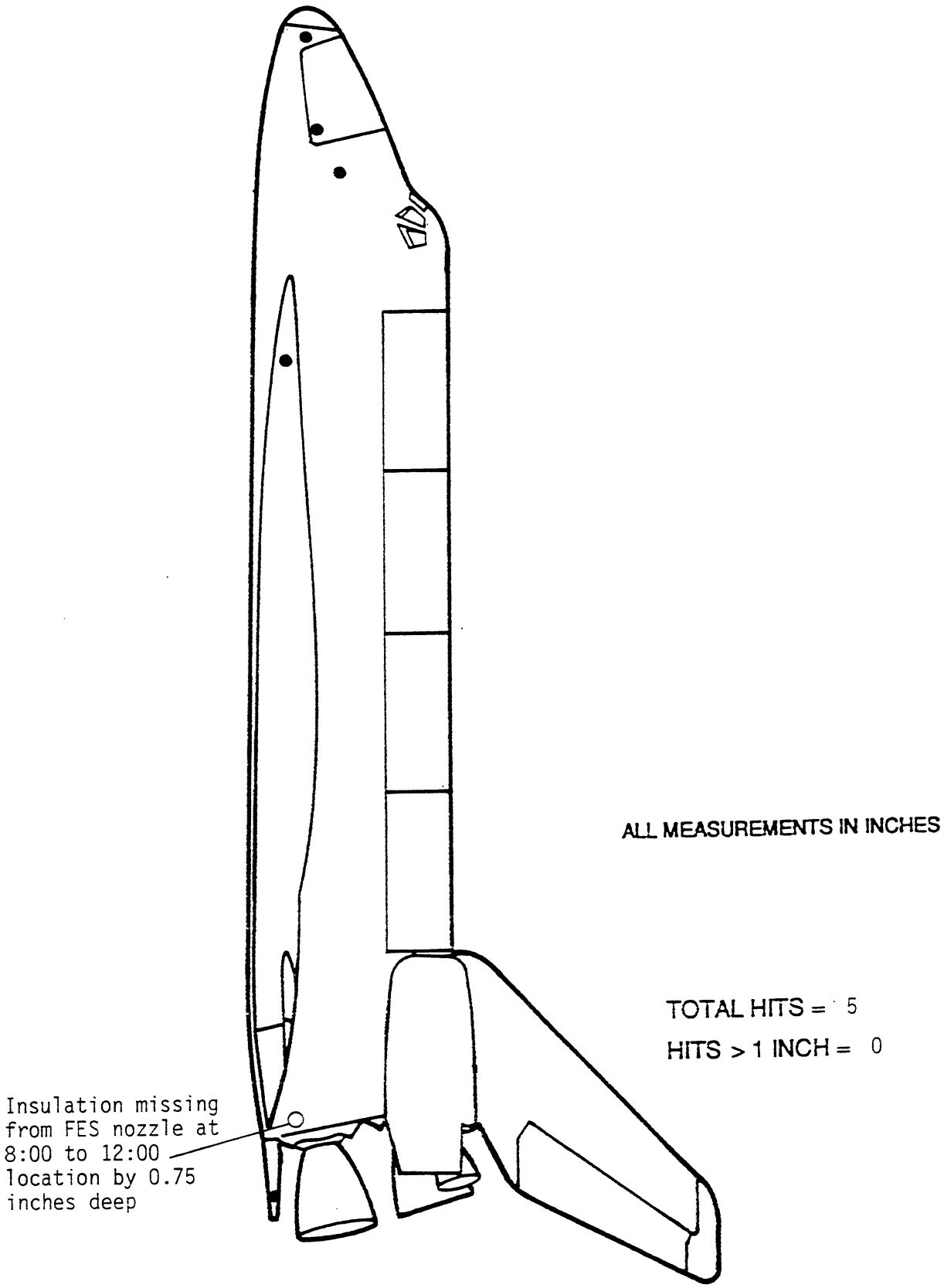


Figure 2: Orbiter Left Side Debris Damage Map

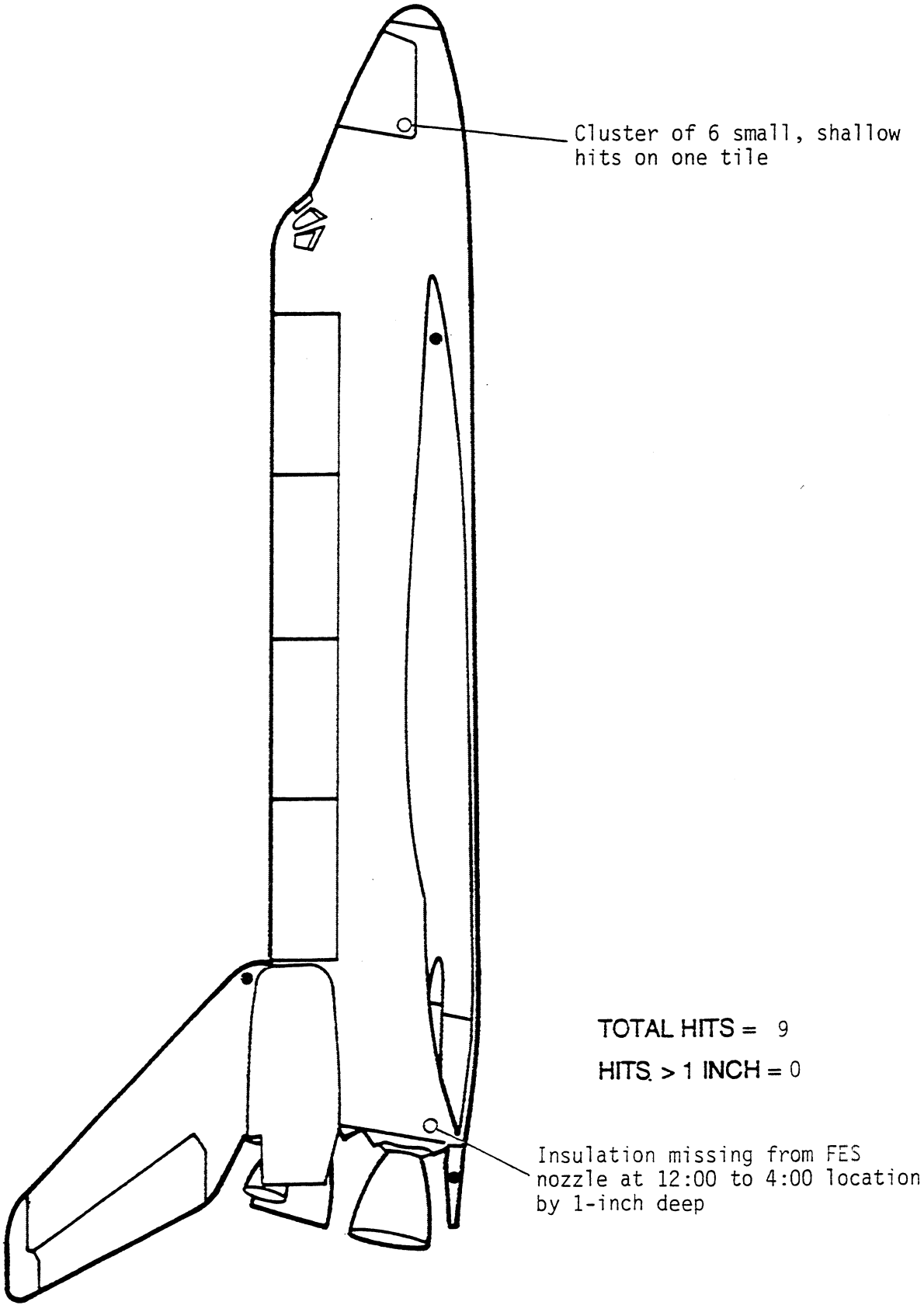


Figure 3: Orbiter Right Side Debris Damage Map

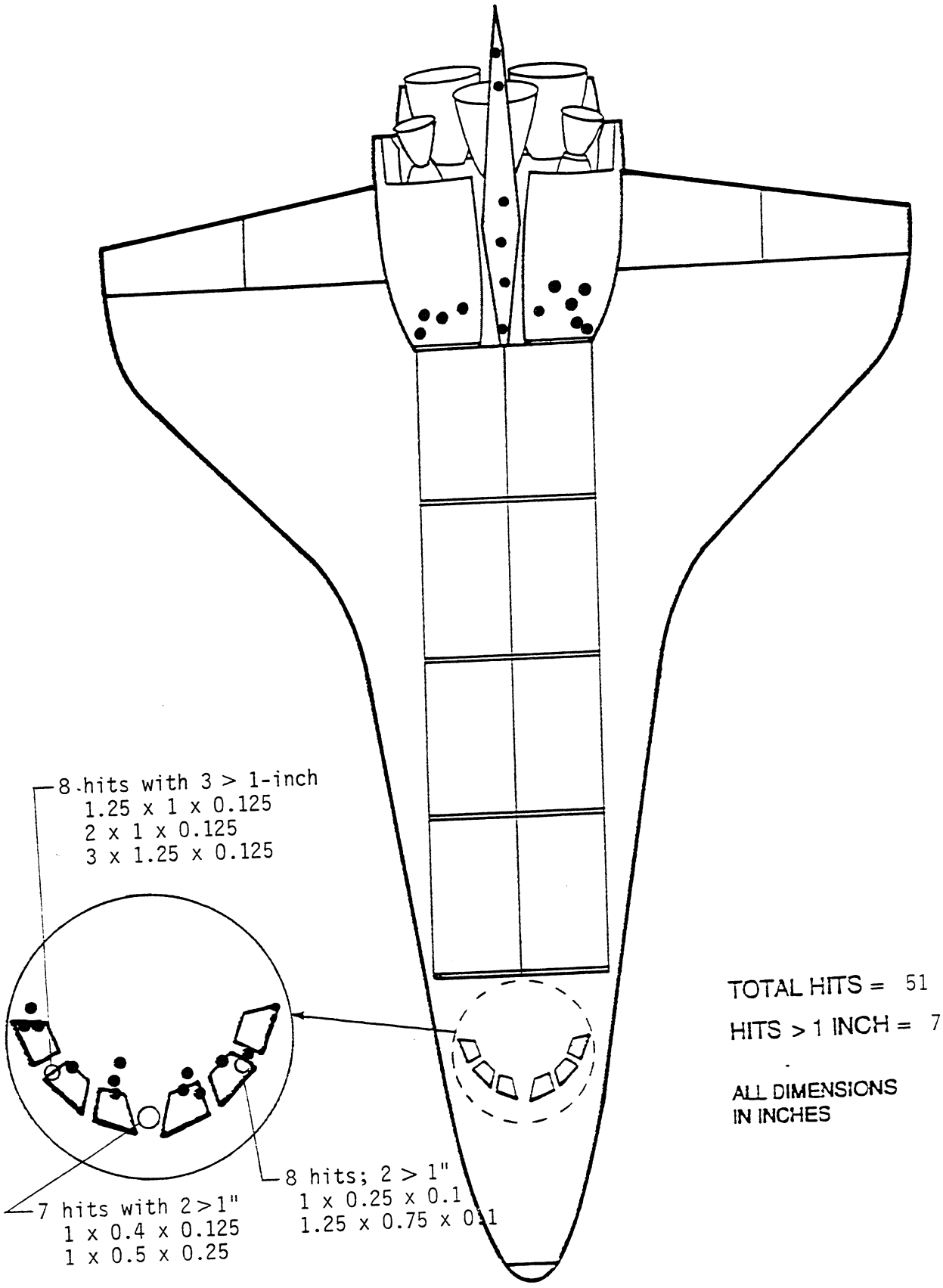


Figure 4: Orbiter Upper Surface Debris Damage Map

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	21	89	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
STS-63	7	84	14	125
STS-67	11	47	13	76
STS-71	24	149	25	164
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
STS-74	17	78	21	116
STS-72	3	23	6	55
STS-75	11	55	17	96
STS-76	5	32	15	69
STS-77	15	48	17	81
STS-78	5	35	12	85
STS-79	8	65	11	103
STS-80	4	34	8	93
STS-81	14	48	15	100
STS-82	14	53	18	103
STS-83	7	38	13	81
STS-84	10	67	13	103
STS-94	11	34	12	90
AVERAGE	13.4	83.9	19.7	124.6
SIGMA	7.1	43.9	9.5	52.2
STS-85	6	37	13	102

MISSIONS STS-23,24,25,26,26R,27R,30R,AND42R ARE NOT INCLUDED IN THIS ANALYSIS
SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 5: Orbiter Post Flight Debris Damage Summary

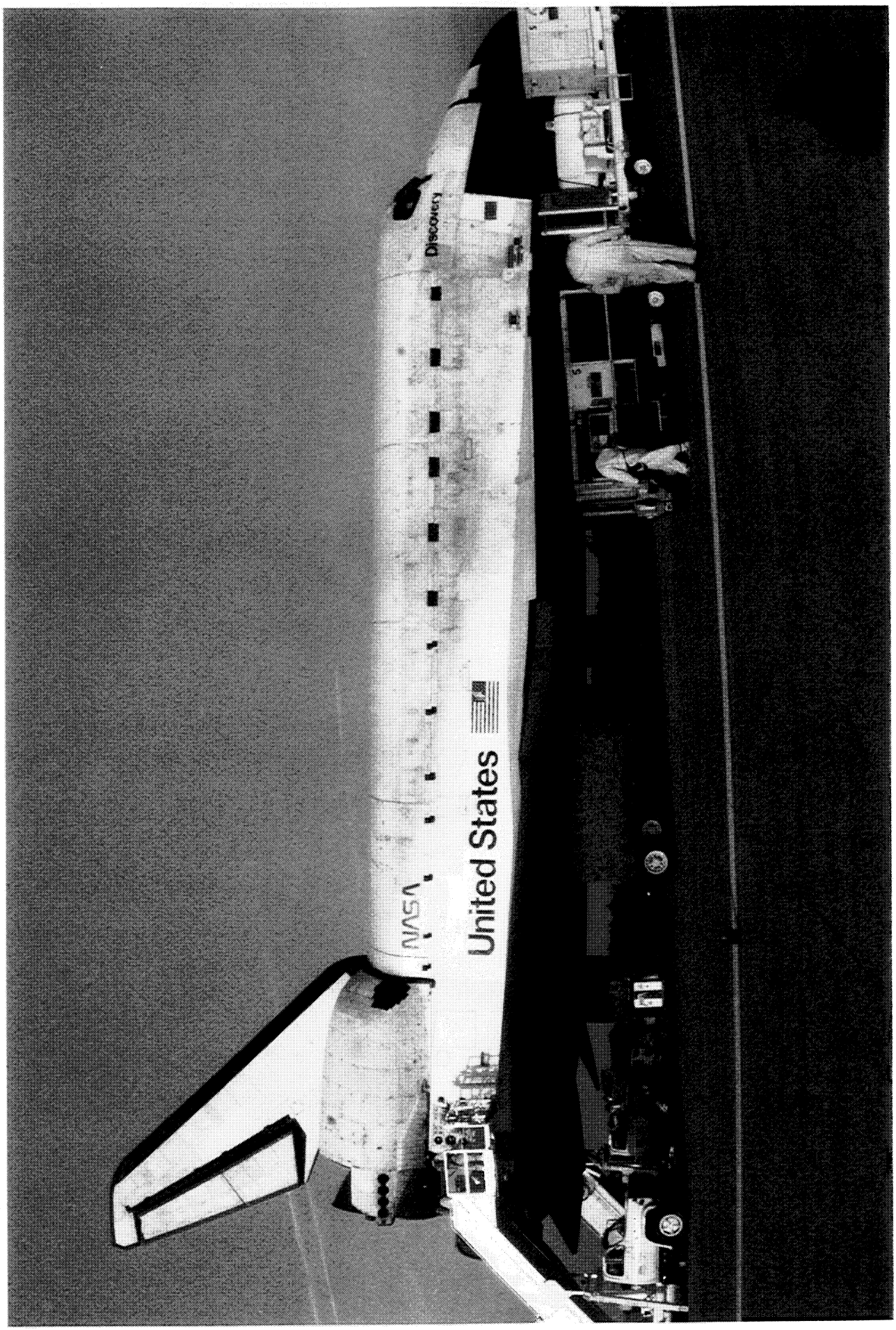


Photo 17: Overall View Orbiter Right Side

Photo 18: Overall View Orbiter Left Side

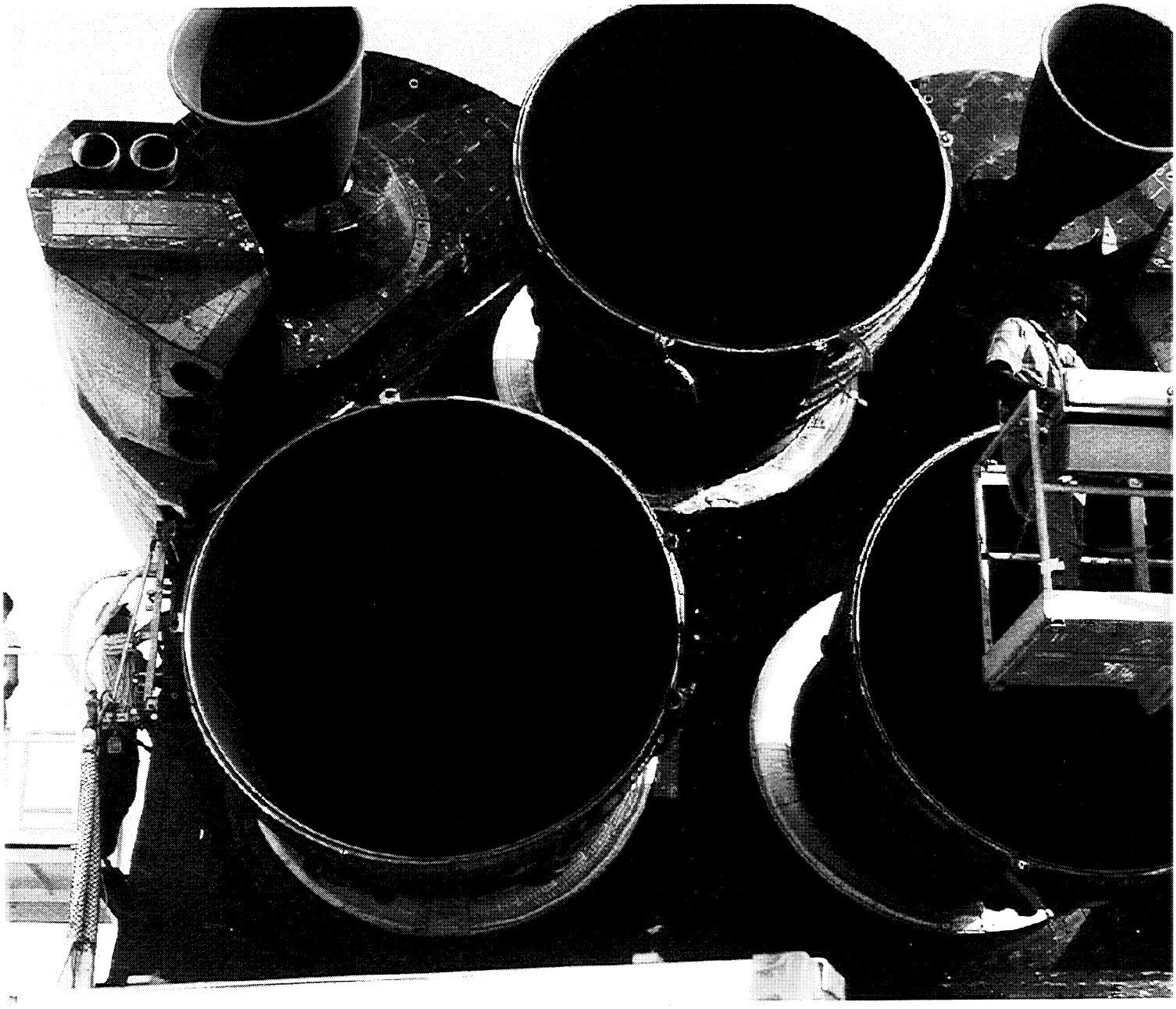


Photo 19: Overall View SSME's and Base Heat Shield

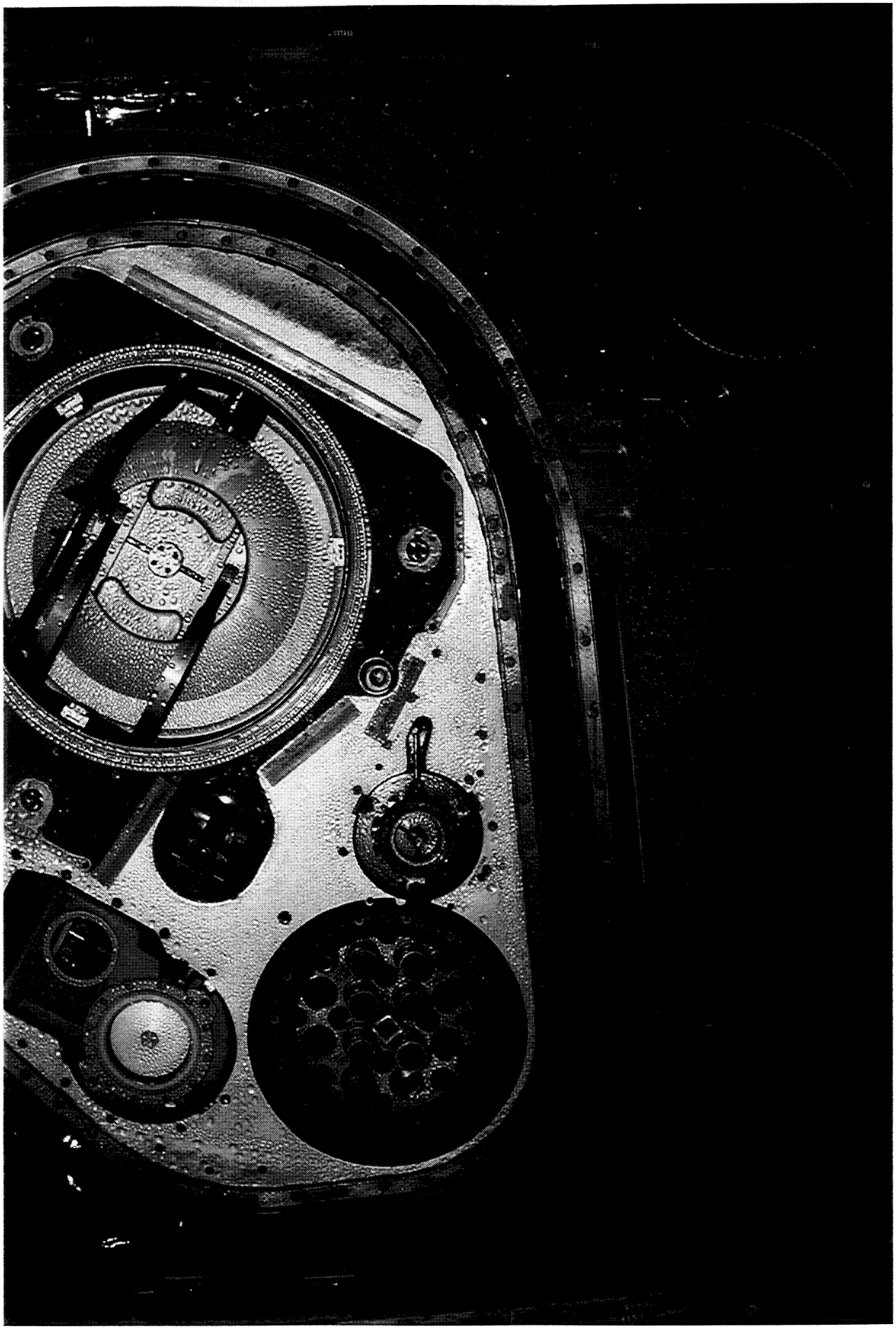


Photo 20: LH2 ET/ORB Umbilical

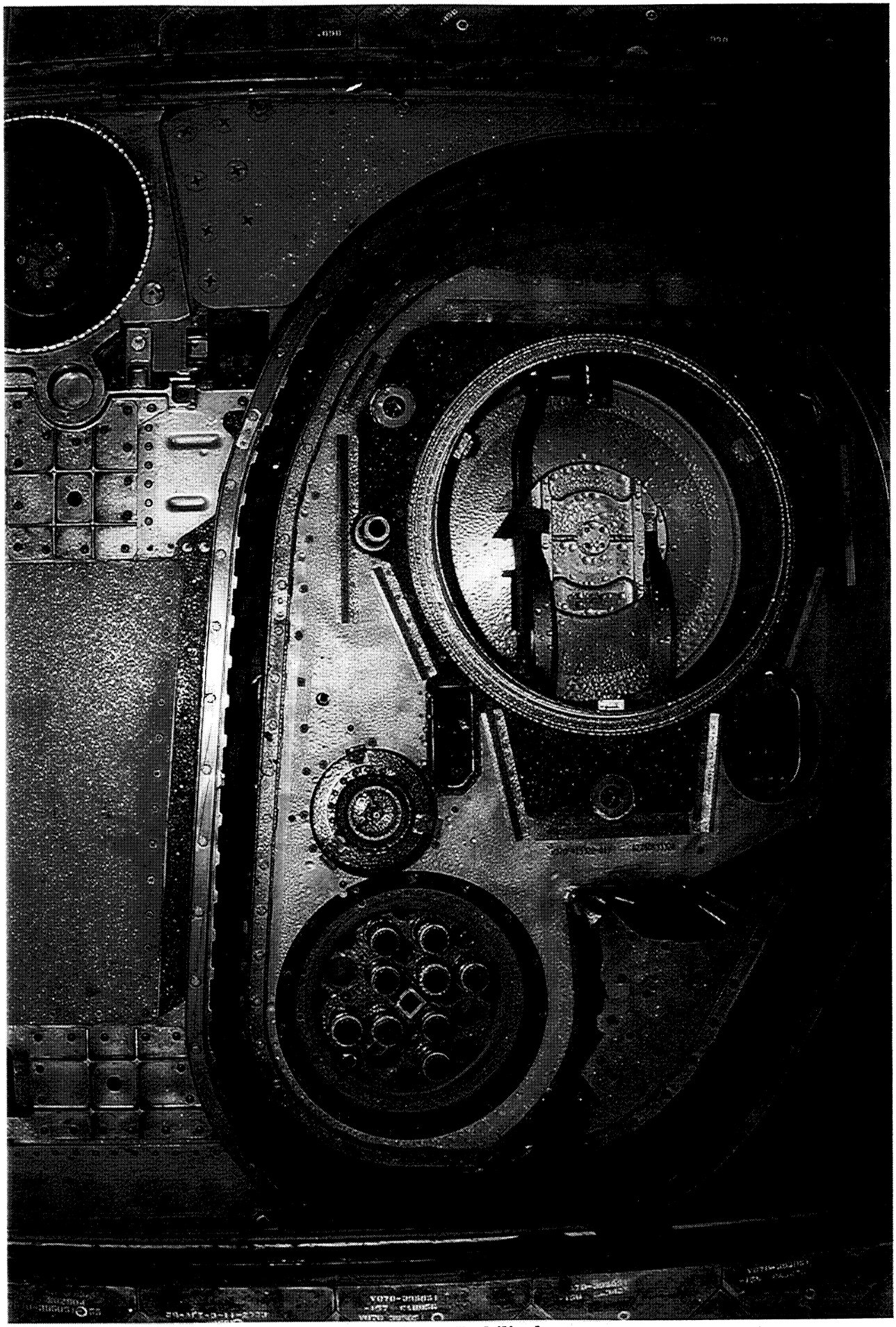


Photo 21: LO2 ET/ORB Umbilical

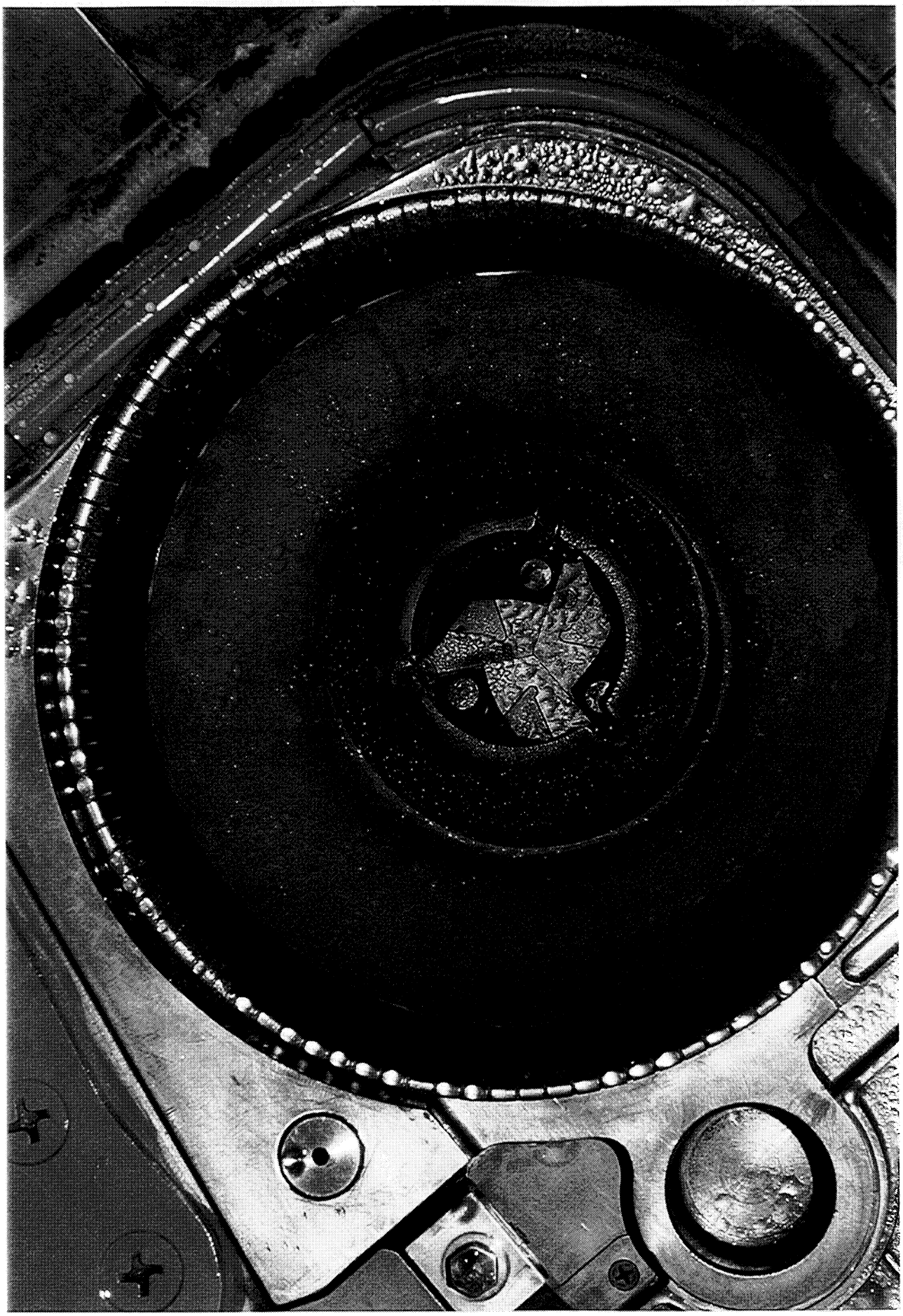


Photo 22: EO-2 Retainer Springs

The EO-2 retainer springs were dislodged. This condition has been observed on previous flights.

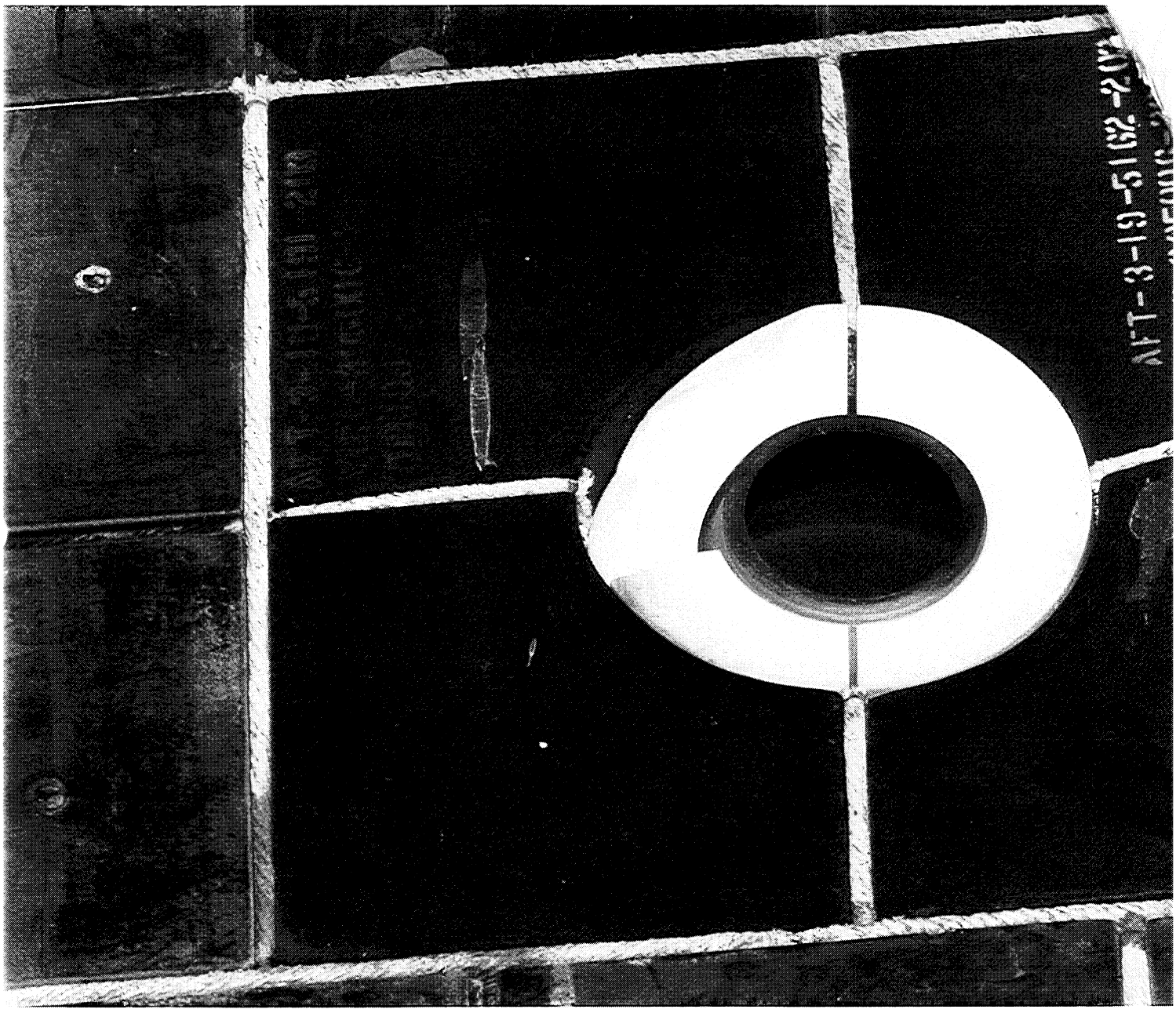


Photo 23: FES Thermal Isolator

An estimated 25-35 percent of the ceramic insulator surface area on both Flash Evaporator vents (aft fuselage near the body flap hinge) was missing to a maximum depth of 1-inch. Review of launch film item E-17 showed the insulator piece from FES #2 falling aft of the Orbiter during SSME ignition at 14:40:56.615 UTC. However, the missing piece from FES #1 could not be detected in the launch films and most likely was lost sometime later in flight.

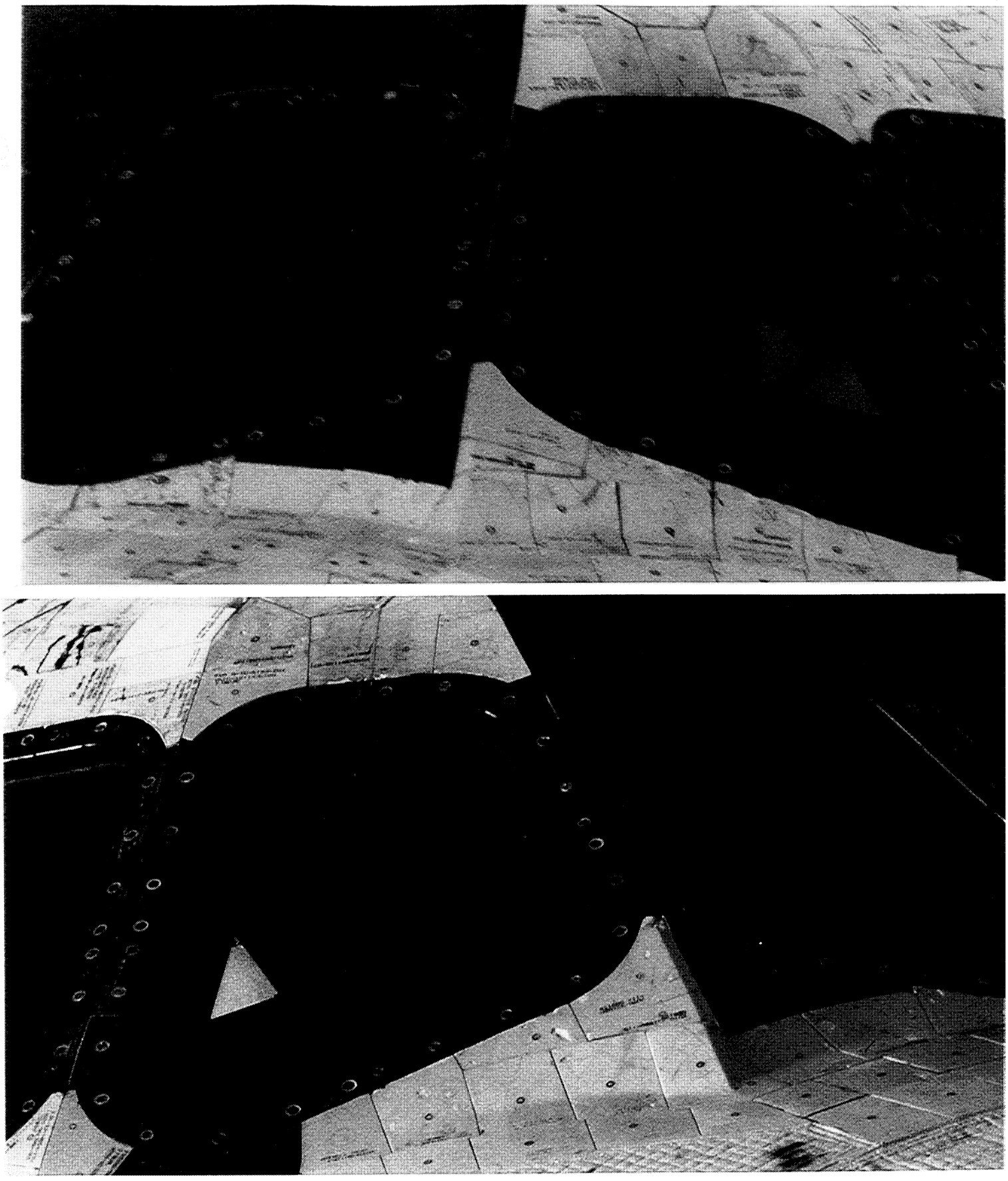


Photo 24: Windows and Perimeter Tiles

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be average in size but more than average in quantity. The damage sites are believed to be the result of impacts from excessive RTV adhesive used in attaching paper covers to the FRCS thrusters.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

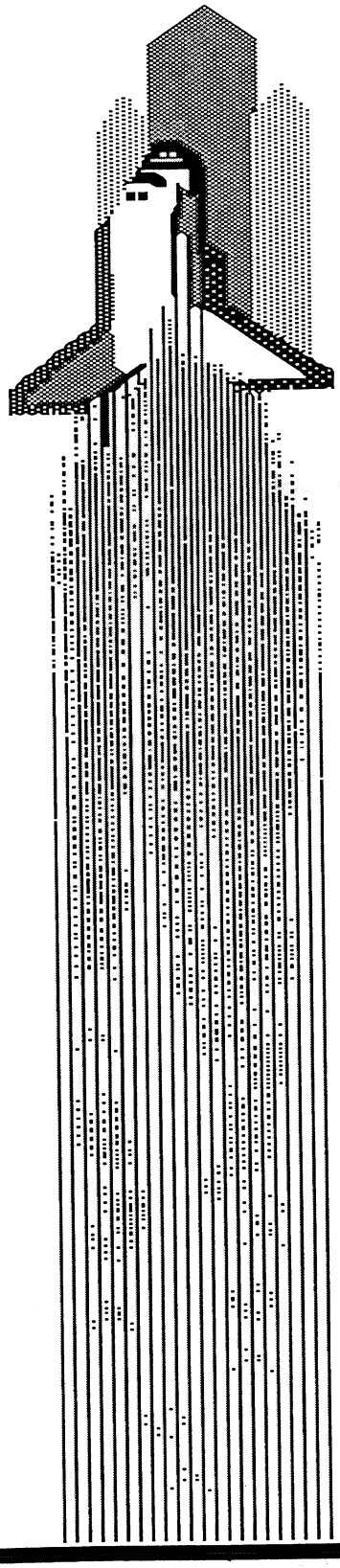
Space Shuttle

Earth Science Branch

Image Science and
Analysis Group

STS-85 Summary of Significant Events

September 17, 1997



Space Shuttle Image Science and Analysis Group

STS-85 Summary of Significant Events

Project Work Order - SN-5LA

Approved By

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Image Science and Analysis Group

for M. H. Trenchard, Project Manager
Image Analysis Projects

Jess G. Carnes, Operations Manager
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Prepared By

Lockheed Martin Engineering and Sciences Company
for
Earth Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

Table of Contents

List of Tables and Figures

1. STS-85 (OV-103): FILM/VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-85 early-morning launch of Discovery (OV-103) from pad A occurred on Thursday, August 7, 1997 (day 219) at 14:41:00.018 Coordinated Universal Time (UTC), as seen on camera E9. Solid Rocket Booster (SRB) separation occurred at 14:43:03.307 UTC, as seen on camera E207.

On launch day, 24 of the 24 expected videos were received and screened. Following launch day, 20 films were screened. Twenty-two additional films were received for contingency support and anomaly resolution, but were not screened since there were no major launch/ascent issues. No anomalies that could threaten vehicle safety were seen on the launch imagery.

Detailed Test Objective 312 was performed using handheld still photography (Method 4). Orbiter OV-103 is not equipped with umbilical well cameras. Therefore, Method 1 was not available.

1.1.2 On-Orbit

No on-orbit analysis support was requested.

1.1.3 Landing

Discovery made an early-morning landing on runway 33 at the KSC Shuttle Landing Facility on August 19, 1997. Twelve videos were received and screened. Following landing, eleven films were screened.

Contrails were seen trailing from the Orbiter wing tips prior to landing.

Although not considered anomalous, APU venting was seen during the approach through roll-out and wheel stop. Flames were seen coming from the APU vent after wheel stop until APU shutdown (Cameras EL17, EL18).

The drag chute deployment appeared normal.

1.1.4 Post Landing

The following items were seen on the post landing walk-around video: a damaged base heat shield tile between SSME #2 and SSME #3, minor tile damage on the right RCS stinger, slight tile damage on the upper surface of the body flap, tile chipping on the aft edge of the left nose gear door, several missing clips on the LO2 ET/Orbiter umbilical well EO-3 fitting, and small ply undercutting marks on the right main landing gear inboard tire.

1.2 TIMING ACTIVITIES

The time codes from videos and films were used to identify specific events during the initial screening process.

The landing and drag chute event times are provided in Table 1.2.

Event Description	Time (UTC)	Camera
Landing Gear Doors Opened	231:11:07:36.116	KTV12L
Left Main Wheel Touchdown	231:11:07:58.027	EL9
Right Main Wheel Touchdown	231:11:07:58.047	EL9
Drag Chute Initiation	231:11:08:00.709	SLF-South
Pilot Chute at Full Inflation	231:11:08:01.727	KTV15L
Bag Release	231:11:08:01.890	EL15
Drag Chute Inflation in Reefed Configuration	231:11:08:03.328	KTV15L
Drag Chute Inflation in Disreefed Configuration	231:11:08:06.732	KTV15L
Nose Wheel Touchdown	231:11:08:08.305	KTV33L
Drag Chute Release	231:11:08:36.562	KTV15L
Wheel Stop	231:11:09:06.959	KTV15L

Table 1.2 Landing Events Timing

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS FROM SSME IGNITION TO LIFTOFF

As on previous missions, multiple pieces of debris were seen near the time of SSME ignition to liftoff (umbilical ice debris, RCS paper, SRB flame duct and water baffle debris). No damage to the vehicle was noted. No follow-up action was requested.

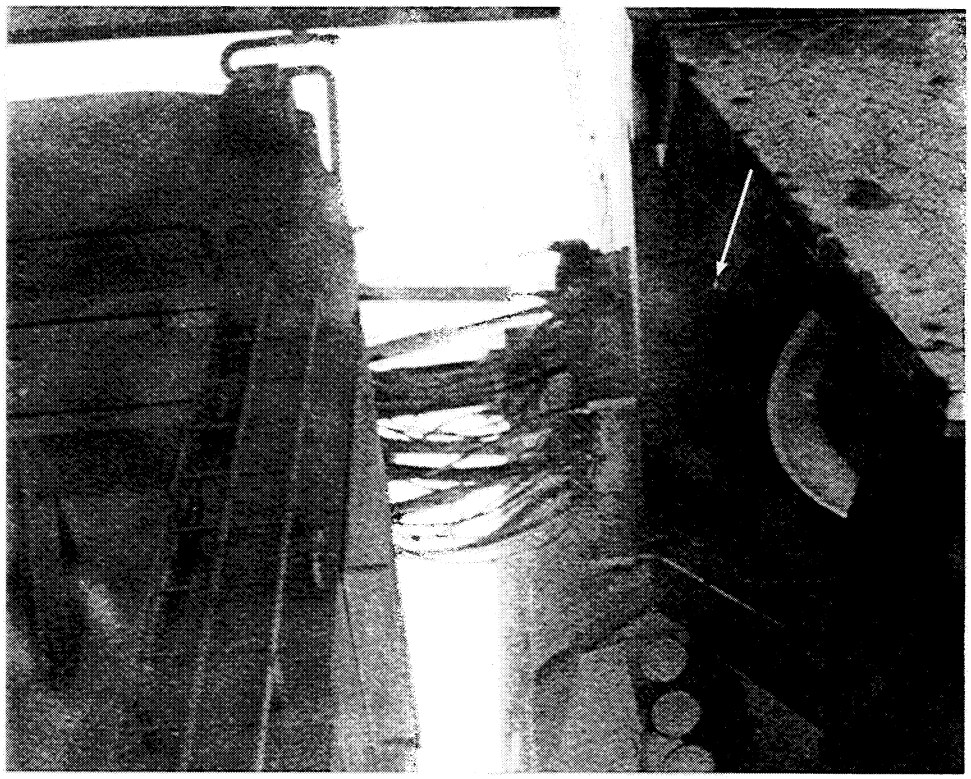

Figure 2.1 (A) Tile Surface Coating Material

A rectangular piece of tile surface coating material was seen to detach from the base heat shield outboard of the base of SSME #2 during SSME startup (14:40:55.505 UTC) (Camera E18).

Three unidentified somewhat triangular-shaped pieces of debris were seen near the LO2 TSM moving toward SSME #3 during SSME startup (14:40:55.555 UTC). Two pieces of irregular-shaped dark-appearing debris (possibly RCS paper) were seen falling along the underside of the right inboard elevon after SSME ignition (14:40:57.346 and 14:40:59.506 UTC) (Camera E17).

Figure 2.1 (B) Debris from ET/Orbiter Forward Area

A light-colored piece of debris was seen falling from an undetermined area forward of the ET/Orbiter umbilicals. This debris may have been close to the camera (14:40:56.4 UTC) (Camera OTV063).

Figure 2.1 (C) Debris near ET/Orbiter Forward Attach Bipod

A single piece of dark-colored debris was seen near the ET/Orbiter forward attach bipod during SSME ignition. This debris moved in an upward direction away from

the vehicle and may have been an insect or a bird. A second piece of light-colored debris was seen aft of the ET/Orbiter forward bipod attach area and fell aft along the port side of the Orbiter. A third piece of debris was seen falling aft of the ET/Orbiter forward attach area between the ET and the Orbiter. None of the debris were seen to contact the vehicle (14:40:56.737 to 14:40:77.9 UTC) (Cameras OTV061, E34).

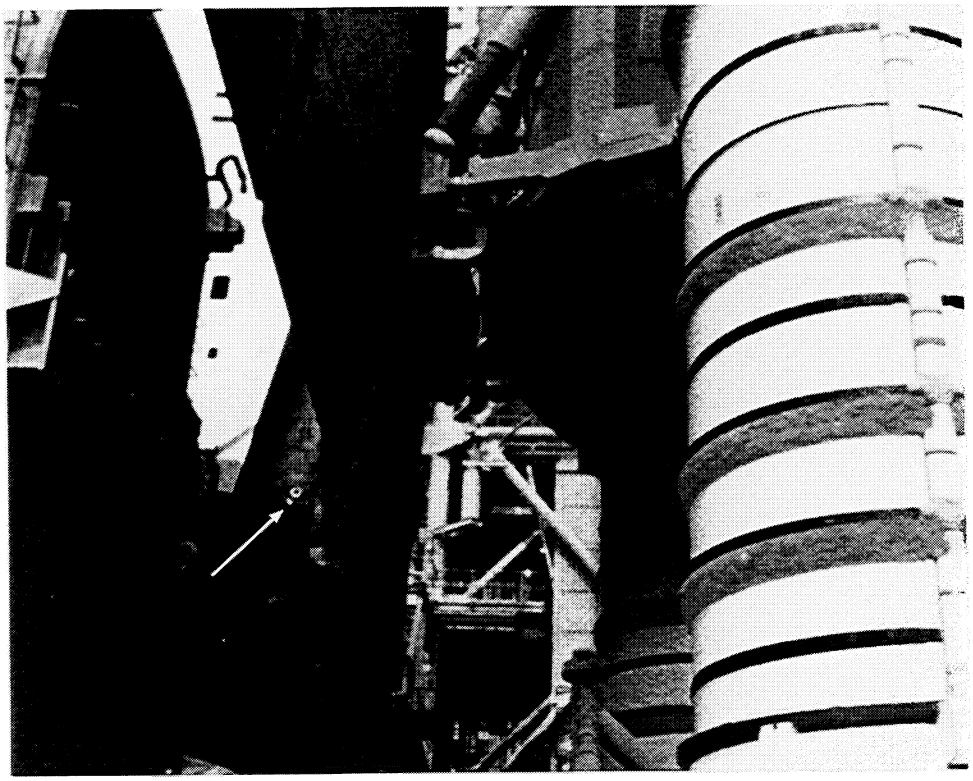

Figure 2.1 (D) Object Detached from FES Top Nozzle

A single, curved, light-colored object appeared to detach (or originate) from Flash Evaporator System (FES) nozzle number two on the right side of the aft fuselage during SSME ignition at 14:40:56.774 UTC (Cameras E5, E17). After landing, KSC reported that 25 to 35 percent of the ceramic thermal insulation surface area was missing on this FES nozzle to a maximum depth of one inch. KSC also reported that a similar amount of ceramic surface material was missing from FES nozzle number one on the port side of the Orbiter. However, the missing material from nozzle number one could not be detected in the launch films and was most likely lost later, in flight. KSC stated that both damaged thermal insulators will be replaced.

Figure 2.1 (E) Ice Debris from ET/Orbiter Umbilicals

A piece of ice debris from the ET/Orbiter umbilicals was seen to strike the ET/Orbiter LO2 umbilical electric cable tray during SSME ignition. No damage to the electric cable tray was visible (14:40:57.137 UTC) (Camera OTV054).

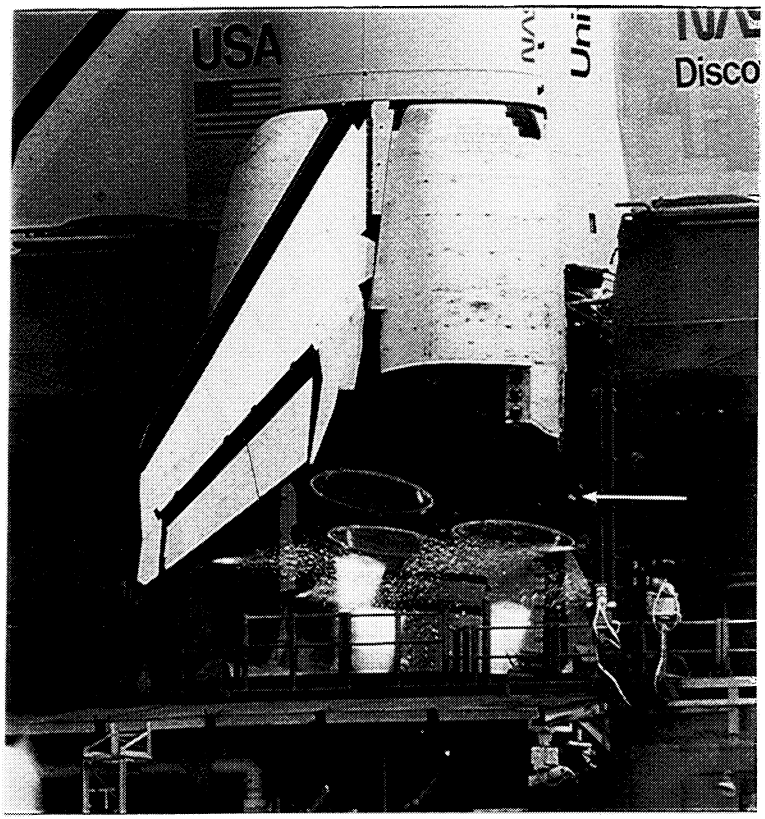

Figure 2.1 (F) Probable Ice Debris from LO2 TSM T-0 Umbilical Area

A large-appearing piece of debris (probably ice) was seen falling from the LO2 TSM T-O umbilical disconnect area prior to liftoff (14:40:58.1 UTC) (Cameras OTV070, E76).

Multiple pieces of debris were seen coming from the RSRB flame duct at liftoff (14:41:00.36 through 14:41:00.79 UTC) (Cameras E1, E2, E4, E5, E17, E31, E52, E76). Some of the debris traveled toward the LO2 TSM. Two pieces of debris from the LSRB flame duct were also seen at the same time. A single, long, thin piece of sound suppression water baffle material, first seen near the RSRB, traveled toward the LSRB.

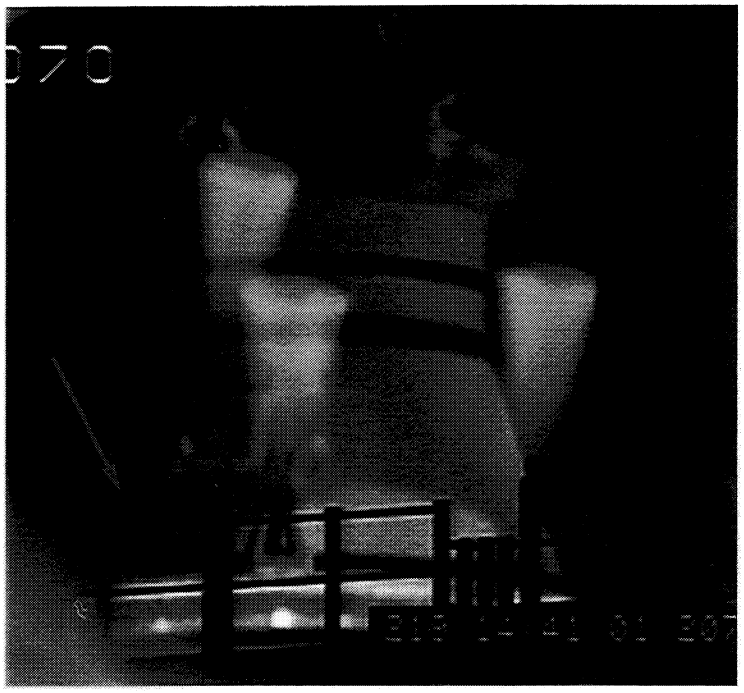

Figure 2.1 (G) Flame Duct Debris near SRB Skirts

Several pieces of SRB flame duct debris were seen between the RSRB aft skirt and the Orbiter, and near the LSRB aft skirt during liftoff (14:41:01.2 UTC) (Camera OTV63).

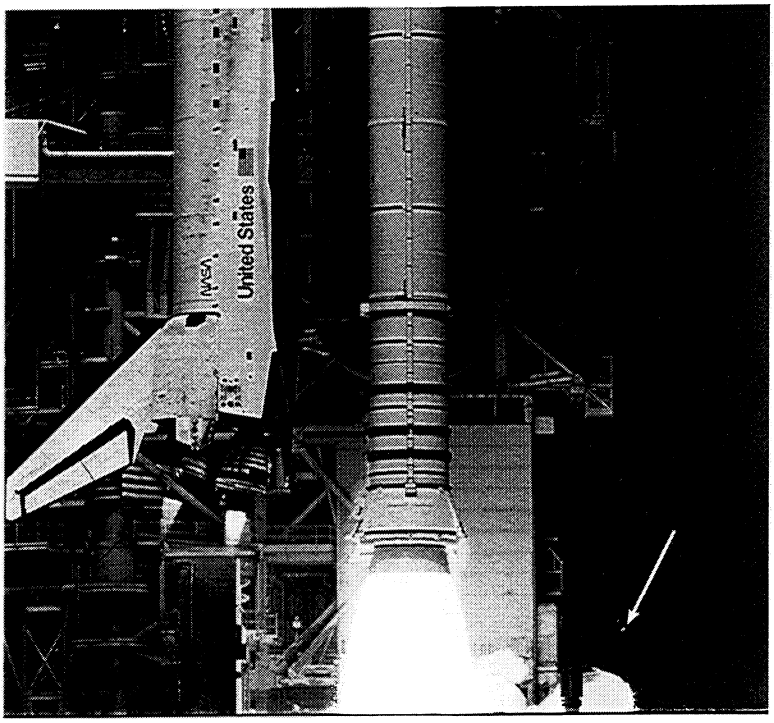

Figure 2.1(H) SRB Flame Duct Material

A single large-appearing light-colored piece of SRB flame duct debris traveled north away from the vehicle during liftoff at 14:41:02.148 UTC (Camera E52).

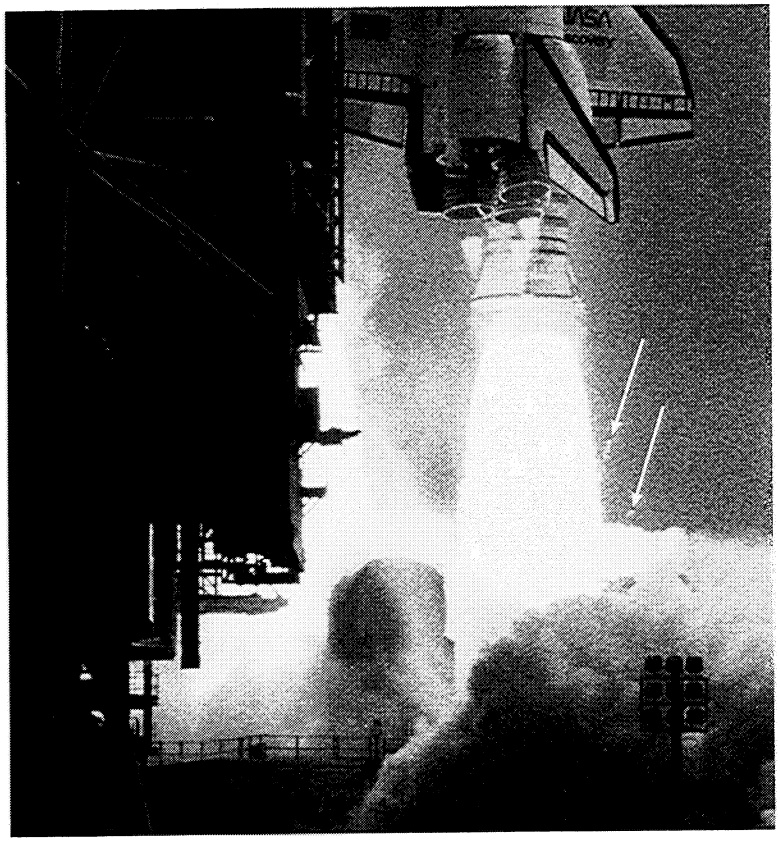

Figure 2.1 (I) Objects with Smoke Trails

Several pieces of debris with smoke trails, which appeared to come from the flame duct, were seen exiting the RSRB plume during liftoff (14:41:02.78 through 14:41:03.085 UTC) (Cameras E2, E20, E63). It is possible that the smoky debris were particles from the large chunk of insta-foam that detached from the RSRB aft skirt during liftoff, which is reported in paragraph 2.3, MLP Events. Water baffle debris and several additional pieces of SRB flame duct debris were also seen in the exhaust cloud after liftoff. None of the debris were seen to contact the vehicle.

2.2 DEBRIS DURING ASCENT

During ascent, multiple pieces of debris (probably umbilical ice) fell aft of the launch vehicle after liftoff to the roll maneuver. Clouds and haze prevented the detection of debris during and after the roll maneuver. No damage to the vehicle was noted as a result of the debris that was noted. No follow-up action was requested. (Cameras E52, E54, KTV4A).

A dark object (probably a bird) was seen falling along the right side of the Orbiter fuselage after liftoff (14:41:03.337 UTC) (Cameras E52, E54).

Light-colored pieces of debris (probably ice from the ET/Orbiter umbilical area) were seen falling along the Orbiter body flap prior to the roll maneuver (14:41:09 UTC) (Camera KTV4A).

2.3 MOBILE LAUNCH PLATFORM (MLP) EVENTS

The SSME #3 Mach diamond formed, disappeared and reformed, as seen on Camera E19 and recorded in Table 2.3. MSFC reported that the disappearance and re-appearance of the Mach diamond on SSME #3 correlated with an oscillation in main chamber pressure that is associated with a characteristic stall and recovery of the Pratt & Whitney high pressure oxidizer pump. The visual phenomenon occurs as a result of a combination of factors including the pump stall, main chamber pressure level, nozzle uniqueness and external environmental conditions. No follow-up action from IS & AG was requested. The times of the Mach diamond formation are provided in Table 2.3.

SSME #3	14:40:56.751 UTC (Formed)
SSME #2	14:40:56.796 UTC (Formed)
SSME #3	14:40:56.796 UTC (Disappeared)
SSME #3	14:40:56.942 UTC (Reappeared)
SSME #1	14:40:57.197 UTC (Formed)

Table 2.3 Mach Diamond Formation

Figure 2.3 (A) Orange Vapor During SSME Ignition

Orange vapor, probably free burning hydrogen, was seen above the SSME rims, under the body flap, and near the base of the vertical stabilizer during ignition (14:40:54.8 - 14:40:55.3 UTC) (Cameras E5, E20, OTV070). Orange vapors have been seen on previous missions.

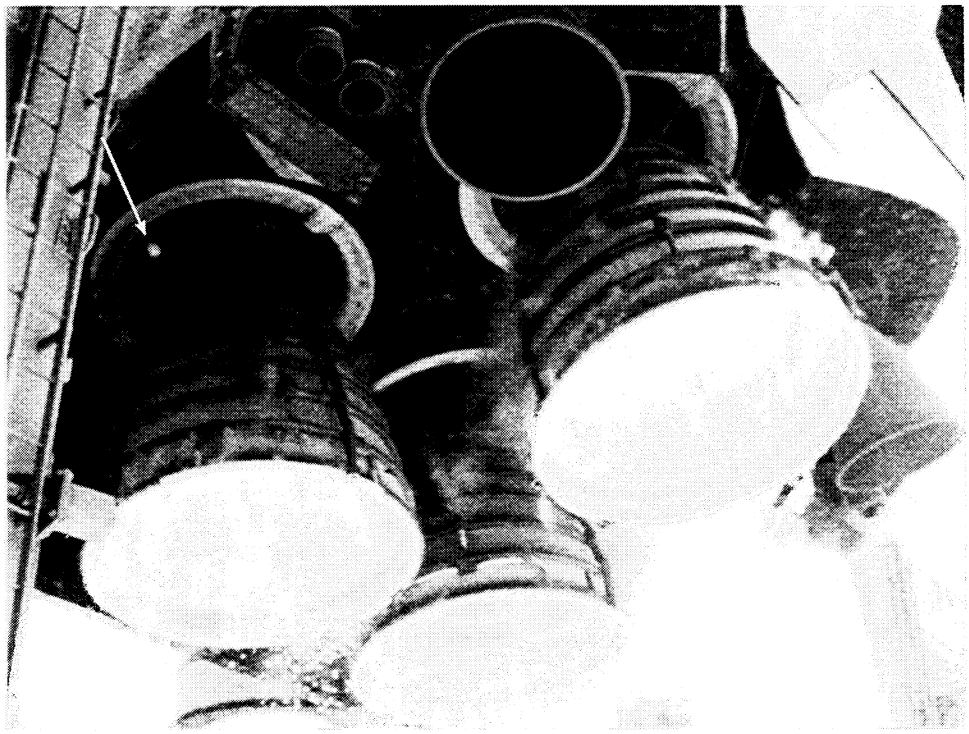

Figure 2.3 (B) Orange-colored Area on SSME #2 Heat Shield

A bright orange-colored area (probably a light reflection) was on the SSME #2 engine mounted heat shield from SSME ignition to liftoff (14:41:00.8 UTC).

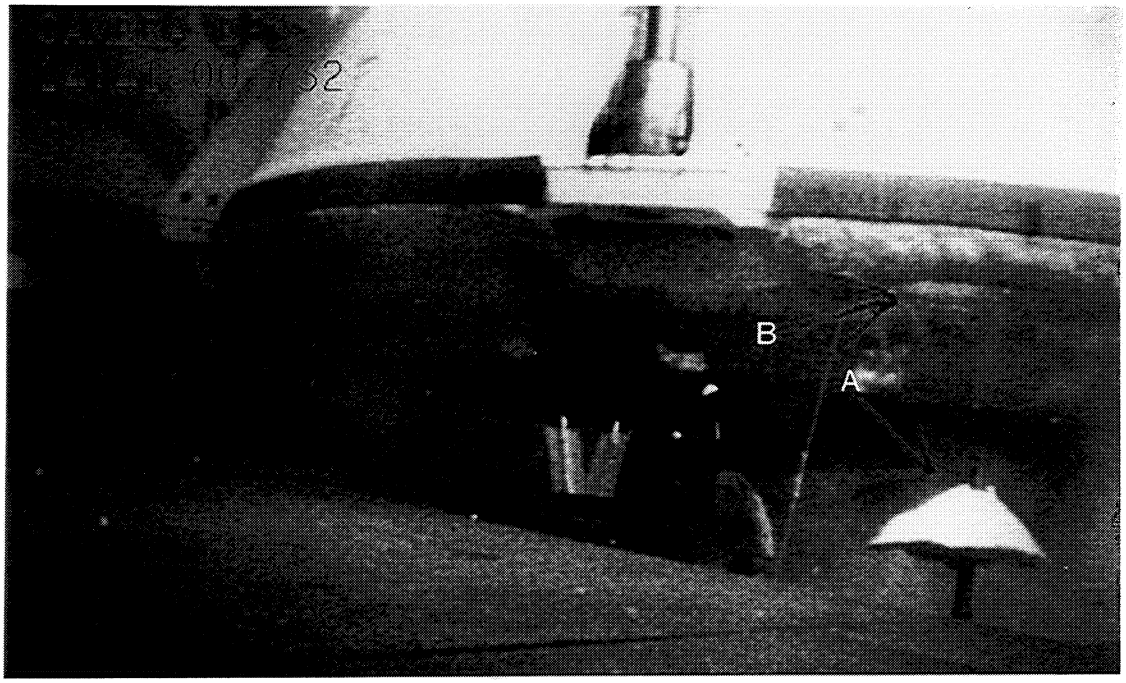

Figure 2.3 (C) Insta-foam Attached to Nitrogen Purge Line

A large thick piece of insta-foam (A), approximately 12 inches in diameter, was pulled loose from the right SRB aft skirt (B) as the launch vehicle lifted off. The foam remained attached to the gaseous nitrogen purge line (Camera E8). The

smoking debris particles shown in Figure 2.1 (I) may have been insta-foam that was pulled loose from the RSRB aft skirt at the same time.

2.4 ASCENT EVENTS

Four orange-colored flares were seen in the SSME exhaust plume during ascent, between 14:41:50.05 and 14:41:50.914 UTC (Cameras E207, E222, E223).

2.5 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

2.5.1 Analysis of Handheld Photography of the ET (Task #3)

DTO-312 handheld photography (Method 4) of the STS-84 ET was acquired after ET separation. A Nikon 35mm camera with a 400mm lens was used (the 2X extender was not used). The +X translation was not performed.

Thirty-seven views of the external tank were acquired (roll 301). Ten views of the -Y axis, ten views of the -Y +Z axes, and eleven views of the +Z axis were acquired. The last 22 views also included views of the nose. Timing data is present on the handheld film. The first picture was taken on August 7, 1997 at 15:02:00 UTC (approximately 21 minutes after liftoff), and the last picture was taken at 15:07:12 UTC.

In addition to the handheld photography, a video of approximately 4 1/2 minutes duration was acquired with a Canon L1 camcorder. The quality of the video was excellent. The same aspects of the ET imaged on the still views were imaged on the video.

No damage to the external tank was seen on the handheld photography or in the video.

The normal SRB separation burn scars and aero-heating marks were noted on the ET TPS.

The visible NCFI 24-124 on the liquid oxygen tank barrel and Ogive appeared in good condition (first flown on STS-94, ET-86). STS-85 was the third flight of the new liquid hydrogen tank sidewall thermal protection system NCFI 24-184 (first flown on STS-84, ET-85). The visible portions of the new liquid hydrogen tank and oxygen tank barrel thermal protection system (TPS) appeared in good condition on the hand-held camera views.

The new LH2 tank aft dome TPS NCFI 24-57 (first flown on STS-79, ET-82) was not imaged. No discernible damage could be seen on the off-center view of the new intertank access door (also first flown on STS-79).

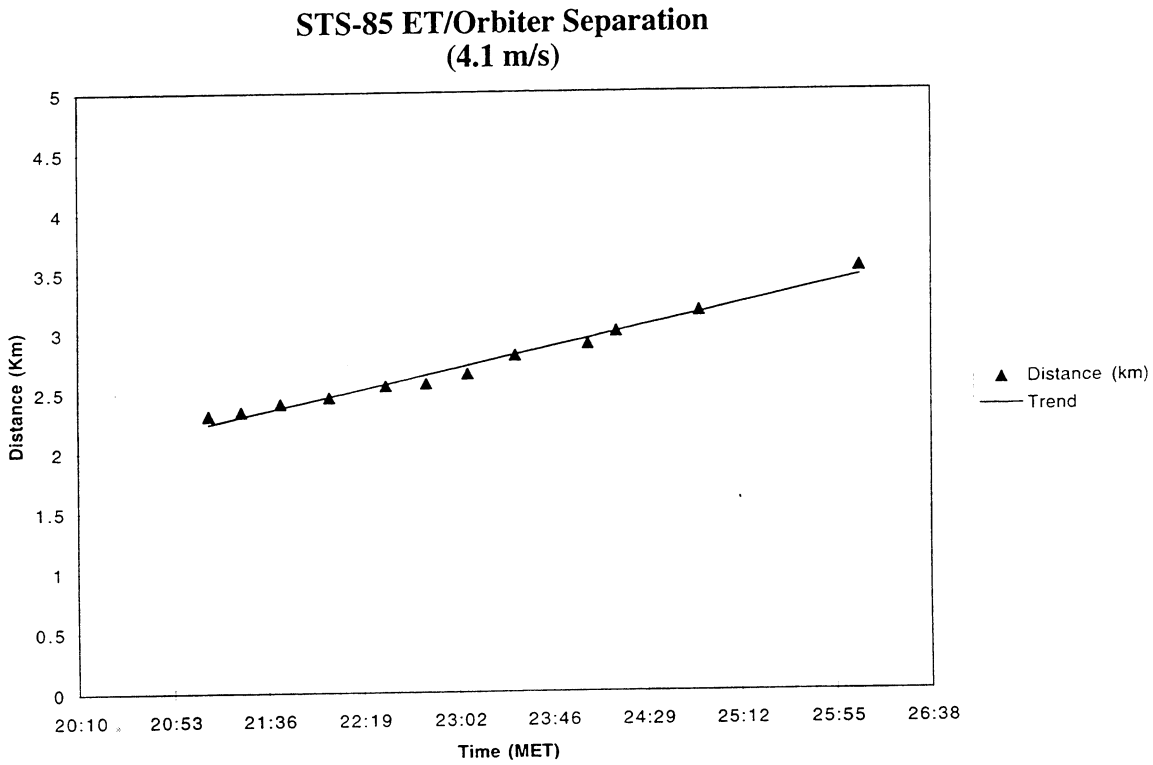

Figure 2.5.2 ET Separation Velocity

The distance of the external tank was calculated on 12 frames. On the first view used, the external tank was calculated to be a distance of 2.3 kilometers away from the Orbiter at 21:09 MET. On the last view, the tank was calculated to be at a distance of 3.5 kilometers (4 minutes, 57 seconds after the first view). The tank separation average velocity was determined to be 4.1 meters/second (m/s), with an uncertainty of approximately 1 m/s. The tank tumble rate was approximately 0.4 degrees/second. The tank roll rate was approximately 0.3 degrees/second.

2.6 LANDING EVENTS

2.6.1 Landing Sink Rate Analysis (Task #1)

Film camera EL9 was used to determine the landing sink rate of the Orbiter main gear and EL12 was used to determine the nose gear sink rate. The sink rates of the Orbiter were determined over a one-second time period prior to main and nose gear touchdown.

The measured main gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS- 85 Orbiter was reported to be 221,184 lbs.). The sink rate measurements for STS-85 are given in Table 2.6.1. In Figure 2.6.1(A), and 2.6.1(B), the trend of the measured data points for the image data is illustrated.

Sink Rate Prior to Touchdown (1 Second)	
Main Gear	1.1 ft/sec.
Nose Gear	3.8 ft/sec.

Table 2.6.1 Sink Rate Measurements

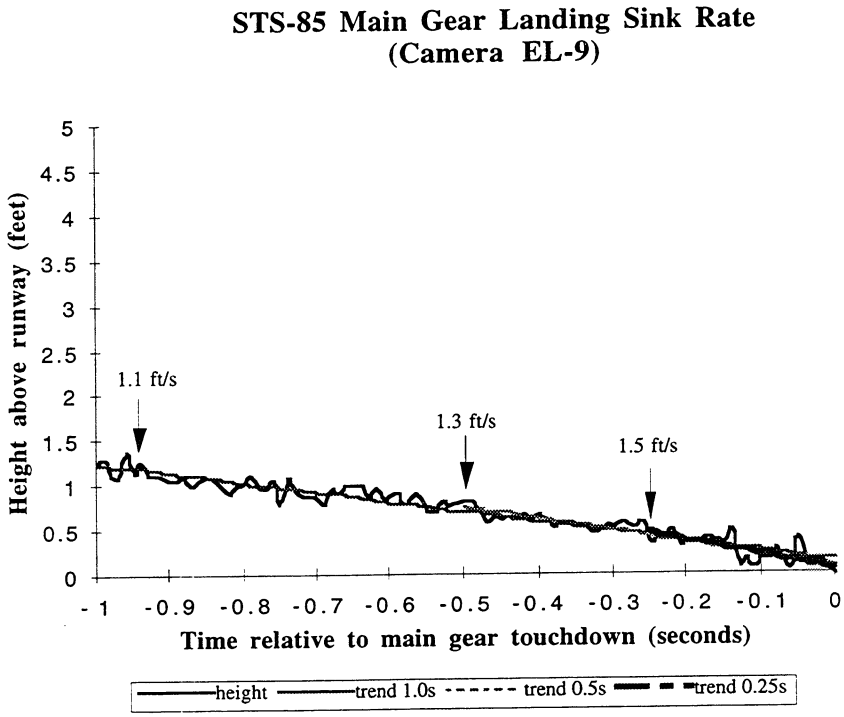

Figure 2.6.1 (A) Main Gear Height versus Time Prior to Touchdown

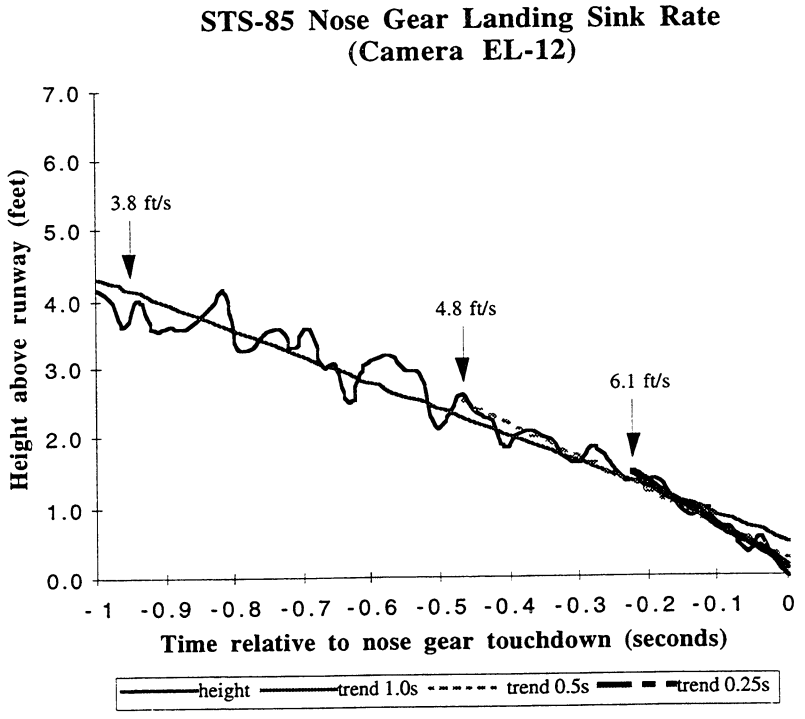

Figure 2.6.1 (B) Nose Gear Height versus Time Prior to Touchdown

2.7 OTHER

2.7.1 Normal Events

Other normal events observed included: ice and vapor from the ET/Orbiter umbilical areas during SSME ignition, elevon motion at SSME ignition, RCS paper debris prior to liftoff, ET twang, multiple pieces of light-colored debris falling from the LH2 and LO2 TSM T-0 umbilicals prior to and following disconnect, birds in view during liftoff, acoustic waves after liftoff, debris in the exhaust cloud after liftoff, vapor off the SRB stiffener rings, roll maneuver, condensation around the Shuttle Launch Vehicle, contrails from the Orbiter wing tips, ET aft dome outgassing and charring of the ET aft dome, slight body flap motion during ascent, linear optical effects, recirculation, SRB brightening prior to SRB separation, SRB separation, and slag debris after SRB separation.

2.7.2 Normal Pad Events

Normal Pad events observed were: Hydrogen ignitor operation, FSS deluge water operation, MLP deluge water activation, sound suppression system water operation, TSM T-O umbilical operations and GH2 vent arm retraction.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Reply to Attn of: EP42 (97-056)

September 9, 1997

TO: Distribution

FROM: EP42/Thomas J. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-85

The launch of Space Shuttle Mission STS-85, the 23rd flight of the Orbiter Discovery, occurred on August 7, 1997, at approximately 9:41 a.m. CDT from Launch Complex 39A, Kennedy Space Center, Florida. Launch time was reported as 97:219:14:41:00.013 universal coordinated time by the Marshall Space Flight Center (MSFC) Flight Evaluation Team. Photographic and video coverage has be evaluated to determine proper operation of the flight hardware.

Atmospheric conditions of haze and cloud cover obscured details from the long-range tracking cameras during the early part of the flight. Because of the lack of visibility, some long-range cameras had difficulty tracking the launch vehicle. Two cameras, E33 and E224, experienced a film jam at start and resulted in no data. Two other cameras experienced a problem with their automatic exposure control system. The Orbiter carried no onboard engineering cameras other than the hand-held 35mm camera used by the astronauts. The astronauts recorded 37 pictures of the external tank after separation.

During the Space Shuttle Main Engine (SSME) startup, the mach diamond of SSME #3 was the first to appear, but then dissipated as the SSME #2 mach diamond formed. SSME #3's mach diamond then reformed, followed by the SSME #1 mach diamond. The apparent dissipation of the mach diamond on SSME correlates with an oscillation in main chamber pressure that is associated with a characteristic hydrodynamic stall and recovery of the Pratt & Whitney high pressure oxidizer pump. This disappearance

and reappearance of the mach diamond is a combination of factors including the pump stall phenomenon, main chamber pressure level, nozzle physical uniqueness, and external environmental conditions.

A chip appeared to fall from a tile on the base heat shield near SSME #2 on the outboard side. The insulation tiles broke away part of their top coating as a result of acoustic vibrations caused by the SSME startup. Another tile appeared to be chipped above the body flap between SSME #2 and SSME #3.

A chunk of Solid Rocket Booster (SRB) aft skirt foam, approximately 12 to 14 inches in its longest dimension, remained attached to the GN2 purge line as the vehicle lifted off.

A piece of debris which left a trail of smoke or vapors was observed between the SRB's as the vehicle lifted off as recorded by camera E62. This debris is believed to be instafoam from the aft skirt that pulled loose and became entrained in the SRB plume.

The following event times were acquired.

EVENT	TIME (UTC)	DATA SOURCE
M-1 PIC Firing	14:41:00.020	Camera E9
M-2 PIC Firing	14:41:00.020	Camera E8
M-5 PIC Firing	14:41:00.022	Camera E12
M-6 PIC Firing	14:41:00.021	Camera E13
SRB Separation	14:43:03.556	Camera E205

This report and additional information are available on the World Wide Web at URL:

http://photo4.msfc.nasa.gov/STS/sts85/sts85.html.

For further information concerning this report, call Tom Rieckhoff at (205)544-7677 or Jeff Hixson, Boeing North American, at (205) 971-3082.

Tom Rieckhoff

Thomas J. Rieckhoff

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A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-85. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs and infrared scanned data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-85 and the resulting effect on the Space Shuttle Program.

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